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THESIS

A MODEL OF THE TACTICAL COMMAND CONTROL PROCESS FOR U.S. ARMY MANEUVER BRIGADES

by

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and
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December 1983

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A Model of the Tactical Command Control Process for U.S. Army Maneuver Brigades

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This thesis examines current decision and control theory and U.S. Army doctrine to develop a systemic model of the U.S. Army tactical command control process. The model is investigated in a simulated brigade delay operation using First Battle. The data obtained from the simulation is used to demonstrate specific analytic tools which have potential for application within the command control process. These quantitative tools are proposed as a supplement to the qualitative analysis performed by the force commander and his staff during combat operations. Prospects for employment of these techniques are enhanced by the current development of automated components within the U.S. Army tactical command control system and by training of personnel in quantitative analysis at the U.S. Army schools and centers.

TABLE OF CONTENTS

I. INTRODUCTION ---------- 8

II. CURRENT COMMAND CONTROL THEORY ---------- 14

A. THE OBJECTIVE FUNCTION OF LAND COMBAT ----- 14

B. THE BINDING CONSTRAINT ---------- 15

C. A SYSTEMS APPROACH ---------- 18

D. DECISION/CONTROL THEORY ---------- 20

III. THE MANEUVER BRIGADE AS A COMBAT SYSTEM ------- 26

A. GENERAL ---------- 26

B. TECHNICAL SUBSYSTEMS ---------- 26

C. SYSTEM INTEGRATION ---------- 29

IV. THE BRIGADE TACTICAL COMMAND CONTROL PROCESS --- 32

A. GENERAL ---------- 32

B. INITIAL PLANNING SEQUENCE ---------- 33

C. CONTROL CYCLE EXECUTION ---------- 46

D. ADDITIONAL CONSIDERATIONS ---------- 51

V. MODEL INVESTIGATION ---------- 53

A. GENERAL ---------- 53

B. SCENARIO ---------- 54

C. ASSUMPTIONS ---------- 56

D. MISSION ---------- 57

E. ENTITIES AND ATTRIBUTES ---------- 58

F. SIMULATION OF THE DELAY ---------- 59

G. INITIAL PLAN FORMULATION ---------- 59

H. CONTROL CYCLE ---------- 74

I. DISCUSSION OF THE SIMULATION ---------- 79

VI. ANALYTIC TECHNIQUES ---------- 81

A. GENERAL ---------- 81

B. CONSTRAINTS ON ANALYTIC TECHNIQUES -------- 82

C. DATA SOURCES FOR FORCE INFORMATION -------- 83

D. ANALYTICS IN THE INITIAL PLANNING SEQUENCE - 85

E. ANALYTICS IN THE CONTROL CYCLE ---------- 110

VII. CONCLUSION ---------- 122

LIST OF REFERENCES ---------- 124

INITIAL DISTRIBUTION LIST ---------- 126

LIST OF FIGURES

1. Initial Planning Process Model ---------- 34

2. Control Cycle Process Model ---------- 35

3. Brigade Sector Schematic ---------- 55

4. Initial Planning Process Model (Numbered) ------- 86

5. Current Force Status ---------- 88

6. Current Maneuver Status ---------- 89

7. Current Fire Support Status ---------- 91

8. Brigade Delay Sector Dimensional Analysis ------- 94

9. Maneuver Force Outcome Projection ---------- 97

10. M1 Tank Outcome Projection ---------- 98

11. TOW (IFV) Outcome Projection ---------- 99

12. Maneuver Force Outcome Projection With Reserve Committed at H+6 Hours ---------- 100

13. Subjective Projection of Outcome ---------- 102

14. Parametric Comparison of Alternative Courses of Action ---------- 103

15. Brigade Weapon System Performance Envelopes ----- 107

16. Brigade Front Line Trace Performance Envelope --- 108

17. Control Cycle Process Model (Numbered) ---------- 111

18. Unit Performance Envelopes ---------- 113

19. Brigade Performance at H+2 Hours ---------- 114

20. Brigade Performance at H+4 Hours ---------- 115

21. Brigade Performance at H+6 Hours ---------- 116

22. Regression Application to Brigade Delay --------- 117

I. INTRODUCTION

> "The real measure of the Maneuver Control System (MCS) is the synergistic effect of the system in enhancing the field commander's ability to influence the battle...the MCS compressed decision making time..." New weapon systems "...increase geometrically the pace and intensity of combat. Something more than acetate, grease pencils and VRC-12 radios is needed to realize the full potential of these systems employed in concert." [Ref. 1]

This excerpt from a message sent by the Commander-In-Chief, United States Army Europe to the Department of the Army Staff, highlights user endorsement of automated support in the U.S. Army tactical command control system. Current manual procedures for transmission, processing and analysis of battlefield information are slow and error prone. The gain in combat potential achieved by weapon system modernization in the U.S. Army may well be negated by an ineffective manual tactical command control system.

The Maneuver Control System is one of many automated systems which are being developed and deployed for use in U.S. Army tactical units. For many years, the Air Ground Operations System has been in use to manage air defense and close air support assets. The automated systems in the U.S. Army Field Artillery were developed to manage the fire support technical subsystem. At a recent Corps Commanders' Conference at Fort Leavenworth, Kansas, the VII Corps Commander, LTG William J. Livsey explained his use of

microcomputers in the VII Corps Tactical Operations Center. All of these examples demonstrate the climate in the U.S. Army which exists to support a transition from manual to automated systems for information communication, processing and analysis.

The challenge which the U.S. Army faces is to achieve this transition by designing and developing systems which satisfy the tactical commander's requirements by appropriate allocation of tasks to men and machines. This transition may require changes to organizational structure, procedures, and facilities. Personnel must be trained to operate and maintain these systems effectively. U.S. Army Doctrine must evolve to reflect the impact of these automated systems on tactics and leadership.

Responsibility for management of automated tactical command control systems in the U.S. Army appears to be in the domain of the Combined Arms Combat Developments Activity (CACDA) located at Fort Leavenworth, Kansas. The Command, Control, Communications and Intelligence Directorate (C^3I) of CACDA is involved in the development of architecture to integrate evolving automated systems into Force Level Maneuver Control (SIGMA). The current architecture which the C^3I Directorate has developed is referred to as the Command Control Subordinate Systems Architecture (CCS^2). This architecture was developed around the manual and automated systems which currently exist within the Air

Defense, Fire Support, Maneuver, Intelligence and Combat Service Support subsystems of the tactical unit or force. A product of this architecture which demonstrates the complexity of the problem is an information exchange matrix of some eighty items of information which are initiated or developed by one or more of the above subsystems and which are required by many or all of the other subsystems to perform their mission. The architecture as developed defines a redundant network of communications and standardized information to achieve automated support for command control within the maneuver force.

Assuming that the communication network is technically feasible, the question becomes one of determining how best to use the available information within the force command control system. The system profile of Force Level Maneuver Control (SIGMA) which describes the time schedule for evolutionary development of the system identifies analytic tools as the post January, 1983 phase. Prior to January, 1983, emphasis was sequentially placed on communications interface, fixed format reports and graphics, reports processing and establishment of a formal data base management system. These phases have been accomplished for the Maneuver Control System and a decision for limited production has been made.

Initially, the thrust of this thesis effort was the development of analytic tools and data manipulation

procedures to assist the force commander and his staff in the execution of their command control responsibilities. However, after detailed examination of the problem, it became apparent that analytic tools must be developed in a systems context to have meaning and utility. Useful analytic tools and data manipulation procedures should aid in battlefield perception, alternative analysis, decision making and control during mission execution. Section II of this thesis provides a brief discussion of the theory of decision and control as it pertains to tactical command control. The section also addresses man's limitations as an information processor with obvious implications for system design and the necessity of a system's approach. In Section III, a systems approach is used to examine the U.S. Army maneuver brigade. The components of the brigade are identified and their relationships are clarified. The concept of system integration is presented. Force integration is achieved via the control exercised by the brigade commander and his staff over the activities of all assigned and attached elements in the brigade. Section IV examines a model of the force command control process. The brigade commander and his staff execute this process to achieve force integration. They gather information, analyze that information, identify problems, generate solutions, direct action and control execution in this cyclical process. Each step in the process is described.

Sections I-IV provide a framework for development of specific analytic tools which may be applied within the force command control process. Similar tools might be developed for command control within each technical subsystem. In this thesis the technical subsystems of the force are the subordinate units of the force which exercise intensive command and control of production and distribution systems. In this context, the direct support field artillery battalion and the combat engineer company are technical subsystems of the supported brigade. Each technical subsystem is controlled by a commander and a formal or informal staff with responsibilities assigned according to functional areas. Personnel services, intelligence, operations and logistics are the functional areas for staff organization which are most frequently identified in company, battalion or brigade level units. The process model described in Section IV was examined for utility in a limited manual simulation using the First Battle Combat Simulation. The simulation was also executed to generate force data which would be obtained in actual combat using Maneuver Control System report formats. Section V provides a description of the simulation and techniques applied within the force command control process to execute a brigade delay. Data obtained from the simulation is presented in Section VI to demonstrate examples of analytic tools which might be employed in the

force command control process. Each technique is related to a specific step in the command control process. Section VII presents the results and conclusions of this thesis.

The United States Army maneuver brigade organic to the mechanized or armored division is the focal point of this analysis. The concepts and techniques developed may be modified for application in other force command control echelons. Major modifications are required to these techniques for application in airborne, airmobile or light infantry forces due to equipment transport limitations. The brigade level was selected for simplicity of structure and facility of simulation utilizing the First Battle manual combat simulation.

II. CURRENT COMMAND CONTROL THEORY

A. THE OBJECTIVE FUNCTION OF LAND COMBAT

> "Combat power is relative, never an absolute, and has meaning only as it compares to that of the enemy. The appropriate combination of maneuver, firepower and protection by a skillful leader within a sound operational plan will turn combat potential into actual combat power. Superior combat power applied at the decisive place and time decides the battle." [Ref. 2: p. 2-4]

The combat commander has the objective to maximize the combat power of his force and to engage his force in combat under advantageous conditions. The concept of combat potential suggests that there is some maximum destructive force which a combat unit can generate at any time on the battlefield. Combat power is the proportion of combat potential which is actually generated by the force as it engages in combat. The amount of combat power actually generated is dependent upon the skill of the leader. "Leadership is the crucial element of combat power." [Ref. 2: p. 2-5] The combat leader is assigned a tactical mission and resources to accomplish that mission. The leader formulates an operational plan to combine the maneuver, firepower and protection assets of his force to generate peak combat power at the decisive place and time. The commander achieves success by sound planning and aggressive execution of the plan. Sound planning requires managerial techniques for the solution of complex problems. Aggressive

execution requires dynamic leadership. The combat commander trains throughout his career to develop these skills.

The October, 1982 Army Magazine documents the dynamic modernization process which is occurring in the U.S. Army. New weapon systems, organizations and doctrine are evolving which increase the combat potential of our forces. New weapon systems possess increased mobility, firepower and protection. The constraint which may restrict the gain in actual combat power generated by these new systems is the ability of the commander to direct and control his forces during combat.

> "Military and civilian leaders on both sides of the Atlantic have frequently touted the theme of force multiplication through command and control." [Ref. 3: p. 1]

While command control may be a combat multiplier, the preceding discussion suggests that a more relevant problem is to provide a minimum level of command control within the force to remove this constraint on the combat potential of the force. The next subsection explores the nature of the constraint created by the leader and a path which may remove the constraint.

B. THE BINDING CONSTRAINT

The combat commander leads a complex system. He seeks to maximize the combat power of his force and to engage his force in combat under advantageous conditions. The tactical command control system exists to assist the commander in the

execution of his leadership responsibilities on the AirLand Battlefield. The leader as a human being has information processing limitations.

> "The mind is excellent at manipulating models that associate words and ideas. But the unaided human mind, when confronted with modern social and technological systems, is not adequate for constructing and interpreting dynamic models that represent changes through time in complex systems...Our mental models are ill defined...assumptions are not clearly identified...The mental model is not easy to communicate to others." [Ref. 4: pp. 3-2, 3-3]

In his book, Decision Making Under Uncertainty, Jerry Felsen documents human information processing limitations:

> "The relatively low capacity of the human sensory channels limits his ability to perceive the current state of the environment. His information storage is slow and unreliable. His modest computing power permits him to deal with only simple mental images of the real world...The human mind performs well when dealing with patterns which are well structured, but of low dimension...abstract and unstructured patterns cannot be efficiently handled by humans as soon as the dimension of the pattern exceeds four. John R. Hayes, (1962) has found that giving a decision maker more than four facts reduces both the quality and speed of his decision. In fact...confusion increases so rapidly that decision makers will perform better if some of the relevant information is eliminated...Decision makers who face these problems are the first to admit that the basis of their decisions is intuitive and qualitative, and could be improved if appropriate quantitative aids were available..." [Ref. 5: p. 5]

Felsen concludes from this analysis that computer oriented approaches are necessary for effective decision analysis due to the increasing complexity and size of systems and the unacceptable conditions created by incorrect or suboptimal

decisions. [Ref. 5: p. 6] Soviet analysts have arrived at similar conclusions:

> "The volume of information at the disposal of the commanders controlling modern combat is so large, and the changes in this information are so rapid that it cannot be processed, and a timely decision cannot be made...the solution of the combat control problem under modern conditions lies on the same path as the control of other complex processes...on the automation paths." [Ref. 6: pp. 309-310]

In an article entitled 'Command Technology', Colonel J. Hemsley asserts that,

> "...the significant point is that in so far as the land battleis concerned, the Soviet armed forces have recognized the demands that the tempo of contemporary combat operations are going to make upon leadership, command and control and the principles are embodied in both doctrine and tactical teaching...Their justifiable concern lies in the fact that technological advances in weapon systems and associated equipments have increased the mobility of operations past the point where human capabilities in terms of assessment and command decisions can match the potential improvement in military performance." [Ref. 7: p. 63]

Colonel Hemsley's statement supports the concept that at a minimum, ineffective command control decreases combat power as a proportion of combat potential. A portion of the combat power of the force has been wasted. While command control may not be a combat multiplier, ineffective command control can waste the combat power generated by lethal weapon systems and trained soldiers.

The human limitations of the commander described above combined with the complexity of the system which he manages suggest that current manual procedures for information processing, analysis, decisionmaking and control guarantee

paralysis or at least reduced effectiveness at the critical point in the battle. Automation within the tactical command control process appears to be a viable solution to this problem. The Maneuver Control System (MCS) is currently being produced for selected deployment to units. The Command Control Subordinate Systems (CCS^2) architecture for automation of command control information processing has been developed to assist the tactical commander in the performance of his leadership functions. The CCS^2 architecture creates a network for sharing of information across the functional areas of maneuver, air defense, fire support, intelligence, and combat service support. The Mitre Corporation has completed a detailed analysis of each subordinate system to determine information requirements and procedures. The CCS^2 architecture is evolutionary. The analytic tools generated in this research effort are products of the information base created by the CCS^2 architecture and reports developed by MCS.

C. A SYSTEMS APPROACH

To gain insight into the tactical unit, it is necessary to examine its organization in terms of its functional characteristics and the manner in which these functional subsystems interact. These functional subsystems operate together for a common purpose. [Ref. 4: p. 1-1] In a military sense, the unit's purpose is twofold,

> "...accomplishment of the assigned mission and the preservation of the force...the tactics of a unit can be viewed as making the most of one's resources." [Ref. 8: p. 2]

The systems approach enables definition of the system to be examined, the environment surrounding the system, the system's resources, its outputs, and its control process. [Ref. 9] The tactical unit, as a system, executes an assigned mission and expends resources in the execution of that mission. This process is dynamic. The state or condition of a unit and its environment change over time.

> "The essential aim of a system dynamics study is to find policies which will control the firm effectively in the face of the shocks which will fall upon it." [Ref. 10: p. 2]

As a system, the tactical unit,

> "...receives inputs of energy, information, and materials from the environment, transforms these, and returns outputs to the environment...The managerial subsystem spans the entire organization by setting goals, and planning, organizing and controlling the necessary activities." [Ref. 11: p. 47]

> "...The essential problem for managers is that of controlling the organization so as to take advantage of favorable opportunities while defending it against ...upsets." [Ref. 10: p. i]

In Section III, the maneuver brigade is examined as a system consisting of functional subsystems of people, processes and facilities which operate together to achieve a common purpose.

D. DECISION/CONTROL THEORY

In an analysis of complex organizations, Herbert Simon identified three layers within the organization:

1. A layer of production and distribution.
2. A layer of programmed (automatic) decision processes for routine operations.
3. A layer of non-programmed decision processes for monitoring the first level processes, redesigning them and changing parameter values [Ref. 12: pp. 49-50].

In a tactical unit, these layers correspond respectively to:

1. Combat, combat support, and combat service support elements at levels from individual crew to company, troop or battery.
2. Standing operating procedures and doctrine which dictate routine actions.
3. The command control system with emphasis on organizations above company level in which a formal staff structure exists to support the commander.

Herbert Simon's frequently used model of intelligence gathering, designing of alternatives and choice of a particular course of action appears to adequately describe the decision making process in tactical units. [Ref. 12: pp. 1-4] The control process is,

> "...that function of the system which provides adjustments in conformance to the plan; the maintenance of variations from system objectives within allowable limits...Control is maintained through a network of information flow..." [Ref. 11: p. 74]

Johnson, Kast and Rosenzweig suggest that measures of effectiveness of the command control system include: stability--ability of the system to maintain a predictable pattern over time, sensitivity--the variation from norms

which occurs before an adjusting response is invoked, and responsiveness--the speed with which the system can correct variations from norms or stated objectives. [Ref. 11: p. 47] If these measures are applied to an effective command control system then that system should reflect stability, sensitivity and responsiveness resulting in mission accomplishment and efficient resource utilization regardless of enemy actions. Theorists are in general agreement that decision processes are dependent upon the flow and processing of information. In a military context, the decision process can be modeled as a two stage activity involving the formulation of an initial plan for an assigned mission and subsequent adjustment of that plan until a new mission is received. This model is described in Section IV.

In the process of making decisions and exercising control over production systems, the commander and his staff must have some common framework to insure unity of effort. This is commonly referred to as a decision strategy. This is not a game theoretical approach. Initially, the number of alternatives is too large, the uncertainty is high and the variables initially are too numerous to allow gaming techniques. Moreover, game approaches do not appear tractable in the dynamic environment of combat. In such an environment, attempts to arrive at an immediate optimal solution may be disastrous. Jerry Felsen describes an iterative process of decision making and control which seeks

to move to the optimal solution in a finite number of steps. The initial decision must be at least within the feasible solution space even if it is not the optimal solution. [Ref. 5] In this context, the commander and his staff seek information in a purposeful manner to reduce uncertainty. Additional information is expensive in terms of time, resources expended and opportunities lost. Quality decisions require establishment of a cause and effect relationship. Stability created by effective command control enables learning to occur at all levels. Correct cause and effect relationships are determined. In examining alternatives and reducing to feasible, desirable alternatives,

> "...options which are both more risky and less profitable are of no interest...the interesting cases are ones where you only get more profit at the expense of more risk and where you can reduce the risk at a cost." [Ref. 13: pp. 41-42]

> "The problem for the controller is to develop a collection of policies which will always produce satisfactory dynamics in the face of any action by the complement. Such a set of policies is said to be robust...Robust policies make the most of opportunities and the best of catastrophes." [Ref. 10: p. 28]

In the context of tactical command control, the complement is the enemy, weather, terrain and intangibles such as fear, fatigue and stress. Quality information not only in terms of the current situation, but also in terms of how the combat situation is changing over time is a principal tool which the commander and his staff must use to

reduce uncertainty and risk. [Ref. 11: p. 8] This concept of information which displays trends over time is a key concept of this study. In terms of system dynamics [Ref. 4], a system is described in terms of its state variables at any time. This is the system's condition. Rates indicate the manner in which the state variables are changing over time. The rate variables determine the change per unit time of the level variables. Forrester states that,

> "...the model of a system must contain one level for each quantity needed to describe the condition of the actual system." [Ref. 4: p. 4-11]

Levels of a combat unit include personnel, weapon systems, fuel, ammunition, time and location.

Control theory suggests that discrepancies between the current state and a desired state can be determined and corrected if the magnitude of the discrepancy is excessive. [Ref. 14] This comparison process is difficult and time consuming in a manual mode but may be reported by exception in an automated system. The commander and his staff must define the desired state in terms of the tactical mission and establish acceptable thresholds for variation. Status reports may be automatically examined to perform the comparison. In situations which defy forecasting, it may be more appropriate to,

> "...devise a control system which would not depend on forecasts but which would respond to current events in a smooth and efficient manner." [Ref. 10: p. 19]

The control cycle is an iterative process of monitoring of system outputs, comparison of actual results with desired results and appropriate adjustments to procedures and resource allocation to accomplish the assigned mission. [Ref. 14]

> "Command and control is the process through which the activities of military forces are directed, coordinated and controlled to accomplish the mission. The process encompasses the personnel, equipment, communications, facilities and procedures necessary to gather and analyze information, to plan for what is to be done, to issue instructions, and to supervise the execution of operations." [Ref. 15: p. 1-1]

The above statement is a succinct description of the tactical command control system. Efforts to improve the performance of the command control system must seek to accommodate human limitations and aid in the reduction of biases and inconsistencies. The leader's ability to make valid decisions may be improved by training as well as by establishment of standardized streamlined procedures for information analysis, planning, plan dissemination and supervision of plan execution. The commander is faced with a dynamic problem. His goal is to accomplish an assigned tactical mission at minimal cost. This goal is confounded by an enemy which seeks to make mission success expensive or impossible. Weather, terrain, and time present additional dimensions of complexity to the commander in his active search for the optimal policy. The commander must rapidly reduce the alternative policies to a single policy which is

simple, feasible and flexible. This search for optimality is a creative process which can be enhanced by systematic procedures and techniques of logic. The recently developed syllabus for the Combined Arms and Service Staff School (CAS^3) includes instruction in quantitative skills, military decisionmaking and other command and staff skills. Such training should improve the skills of staff officers and commanders to execute their duties effectively.

III. THE MANEUVER BRIGADE AS A COMBAT SYSTEM

A. GENERAL

In this section, the maneuver brigade is examined as a combat system. Herbert Simon's paradigm of the layers of an organization is used to identify the production and distribution components of the brigade, the layer of programmed decisions and the layer of unprogrammed decisions. [Ref. 12] A concept of system integration is developed to describe the manner in which these layers are combined into a combat force. This integration is achieved by the force command and control system.

B. TECHNICAL SUBSYSTEMS

In terms of Herbert Simon's paradigm of the layers within an organization, the maneuver brigade can be examined as a system. At the production and distribution layer, units are organized to perform specialized functions. Specialilzed units which are normally found within a maneuver brigade include maneuver, fire support, air defense, engineer, intelligence, signal, medical, maintenance and supply. Other units sometimes included are aviation, transportation, military police and chemical. Each of these units constitutes a technical subsystem with an identifiable internal technical command control system.

Each unit has a commander and formal or informal staff organized to execute detailed management and leadership of the technical subsystem. [Ref. 15: p. 2-1] The maneuver command control system performs a dual function. It intensively manages the assigned maneuver forces and coordinates and directs the activities of the other technical subsystems to support the maneuver force in the execution of the tactical mission. The unifying document for the execution of a coordinated effort by all subsystems in concert is the brigade operations order. Each subsystem commander leads his unit and directs actions consistent with the brigade commander's concept and the resource constraints imposed. The brigade commander and his staff are referred to as the force command control element. The brigade staff is the focal point for force information and coordination. The number, thirteen or more, and complexity of these technical subsystems frustrate efforts by the brigade commander and his staff to exercise intensive management of every subsystem. The alternative is to decentralize control and to intensively manage only the areas which are most critical; those which clearly endanger or guarantee mission success. In this light, the brigade commander and his staff formulate ground tactical plans and coordinate support of those plans with the command control elements of the other technical subsystems. Within this relational framework, procedures and techniques must be developed to streamline

the command control process to achieve the goals of AirLand Battle Doctrine. Section VI addresses specific tools which may contribute to this goal.

Simon's layer of programmed decisions within each technical subsystem consists of formal and informal standing operating procedures and policies which dictate action in routine or pre-planned situations. Such procedures include standard reporting policies, communication frequency assignments, vehicle loading diagrams, emergency signals and numerous other procedures peculiar to a specific technical subsystem or to the force as a whole. These policies will change with a change in the operating environment and the tactical mission assigned to the force. In the light of such complex dependencies, few situations can be labeled as routine. For each technical subsystem and for the force, policies must be formulated which minimize the impact of such dependencies and which contribute to maximizing combat power. In terms of rapid reorganization and reconstitution on the AirLand Battlefield, standardization across forces of similar types is essential as well.

Simon's layer of unprogrammed decisions within the maneuver brigade is provided by the brigade commander and his staff. Each unprogrammed, non-routine decision requires coordination, analysis, a decision, communication of the decision and supervision of execution. Such a process consumes critical resources to include time. Delays may

create confusion and wasted combat power. All situations cannot be anticipated but sound planning and coordination within the force may minimize the occurrence of situations requiring unprogrammed decisions or management by exception. Sound planning will free the brigade commander and his staff to concentrate their efforts on the critical aspects and decisions which contribute directly to mission success.

C. SYSTEM INTEGRATION

1. Vertical Integration

Each technical subsystem consumes resources as it executes assigned missions. It generates technical detailed information about its condition or state and communicates that information within functional or technical channels. This information is aggregated as it moves through the production, operational and planning levels of the organization. The aggregated information provides the subsystem commander and his staff with a comparison capability to establish priorities and adjust policies in a dynamic environment. Unit personnel, situation, intelligence and logistic reports generate this technical data base. The technical data may be manipulated to create more general staff information which describes the condition of a unit at a specific level of personnel or weapon system strength. The Maneuver Control Data Base Management System

seeks to standardize this technical data base. [Ref. 16: pp. 444-446]

2. Horizontal Integration

In terms of force control and coordination, information must be shared across functional areas and technical subsystems. The Command Control Subordinate Systems (CCS^2) architecture imposes requirements to achieve this goal. In many cases, a single technical subsystem supports all or many other technical subsystems. The brigade ammunition supply point, for example, services all units and requires information about unit basic loads and on-hand quantities to manage resupply policies. The brigade commander and his staff require information about fire support and air defense assets which may impact on mission success. Information generated by the intelligence subsystem is required by the fire support subsystem to execute its interdiction mission.

3. Longitudinal Integration

At all levels of the system from technical to strategic levels of command control, tracking and analysis of the change in subsystem levels over time enables evaluation of performance and prediction of the future conditions of the system. Graphical display and comparison of trends in similar units may suggest revised policies for resource allocation to maintain units at acceptable levels of personnel, weapon systems, maintenance and supply.

Trends developed by the intelligence subsystem may create an identifiable pattern of enemy activity which reduces the commander's uncertainty of the enemy course of action. Specific examples of trend maps are described in Section VI.

4. Force Integration

The description of the maneuver brigade as a system must include an understanding of the external environment. The brigade is a subsystem of the division. The brigade command control system coordinates with adjacent maneuver units and with the division command control system.

Tactical missions and resources are assigned to the maneuver brigade by the division. Designation of the main effort by the division operations plan dictates the relationship between adjacent brigades. Technical information concerning the enemy, weather and terrain are provided to the brigade by divisional assets. The maneuver brigade, then, is a level in the hierarchy of force command control systems.

IV. THE BRIGADE TACTICAL COMMAND CONTROL PROCESS

A. GENERAL

The brigade tactical command control system consists of personnel, facilities and procedures to analyze information, plan operations, direct action and to supervise execution of directives. [Ref. 15: p. 1-1] More generally, this system is referred to as force command control. This system integrates the activities of the technical subsystems within the force to accomplish the assigned tactical mission. The personnel who perform this function are the maneuver unit commander and his coordinating and special staff. The facilities which they use include map displays, information centers, and communication equipment. The procedures which they employ to accomplish their tasks are imbedded in the tactical command control process. This process is designed to purposefully analyze information to determine what is currently being done, to compare the current situation with the mission-defined desired situation and to develop and direct corrective action as necessary.

Frequently, the critical constraint imposed on the command control system is the time available to analyze information, select a course of action and communicate that course of action to units for execution. The effectiveness of the tactical command control system is improved by

training of personnel, standardizing and streamlining the process and designing efficient facilities for information processing and analysis. The focal point of system improvements must be the procedures which are performed. Some procedures may be executed automatically using computers. Others require a creative process which is a more appropriate endeavor of the commander and his staff. This section elaborates a detailed model of the tactical command control process. The process appears to have two distinct phases: Formulation of the initial plan and execution of the control cycle. A schematic diagram of the initial planning phase is shown as Figure 1. Figure 2 depicts the control cycle.

B. INITIAL PLANNING SEQUENCE

This phase of the tactical command control process is a formal, detailed sequence which normally begins with the assignment of a new tactical mission or a substantial change in the requirements of the current mission. The time constraint may require modification or abbreviation of this sequence. Adherence to this general process should result in selection and execution of a feasible course of action in a timely manner. Examination of each step in the sequence provides an opportunity for appropriate allocation of tasks to personnel and computers as well as specific methods to accomplish tasks. Such methods include standard information

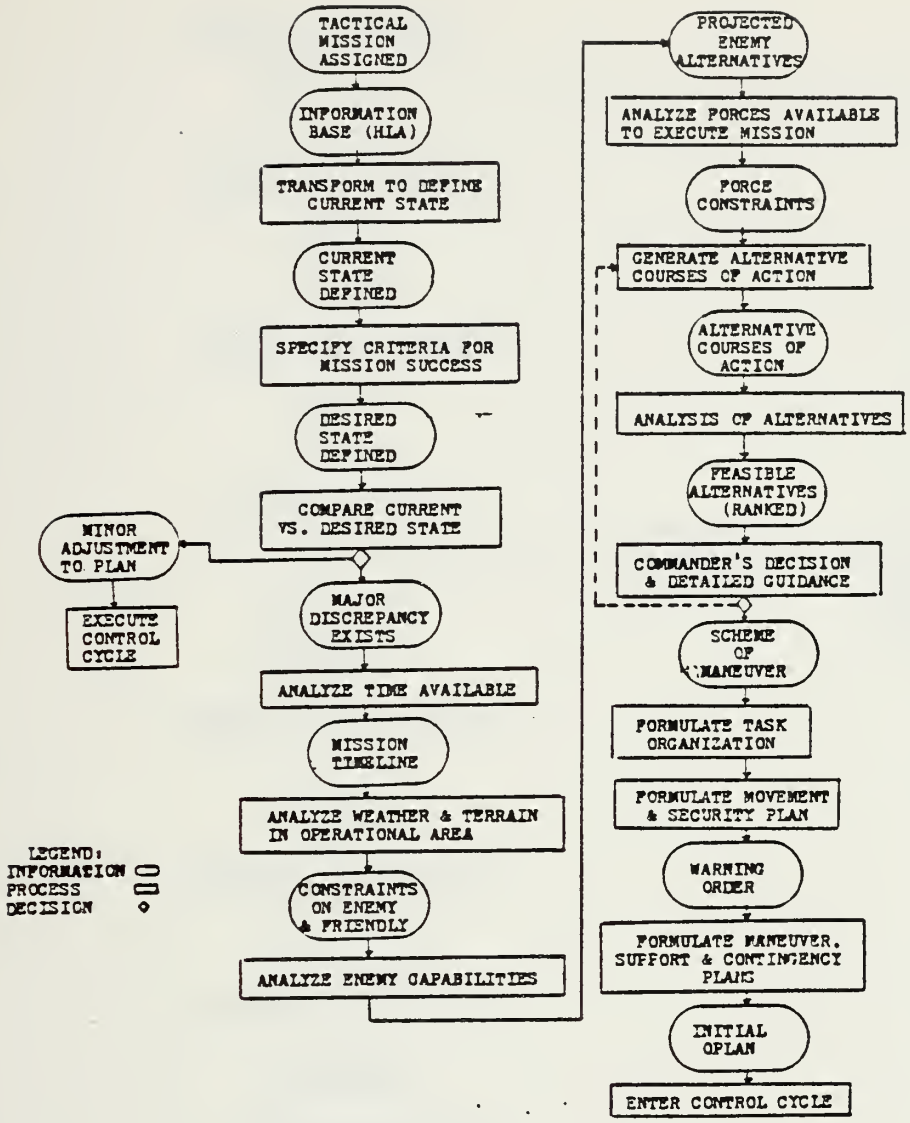

Figure 1. Initial Planning Process Model

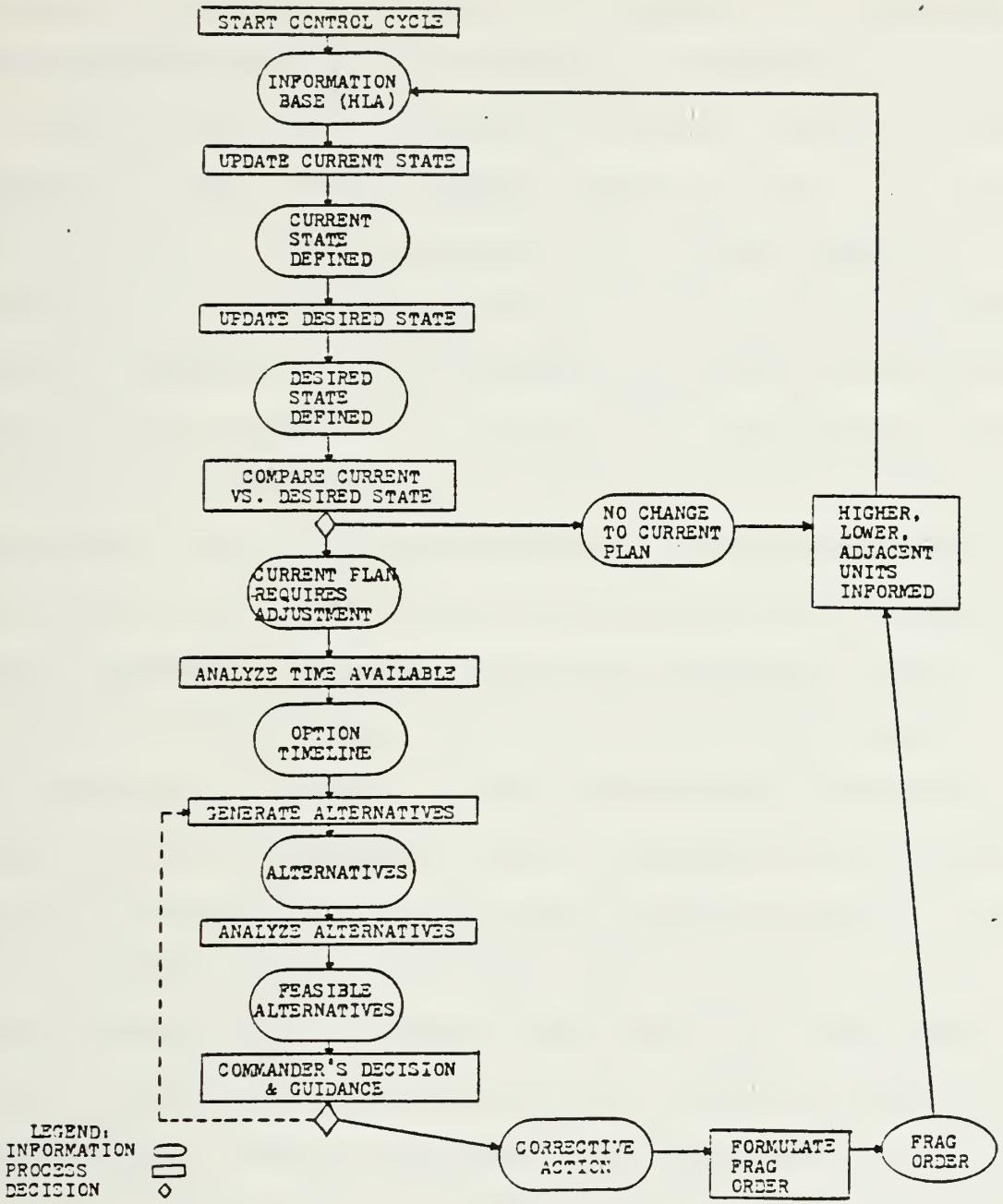

Figure 2. Control Cycle Process Model

displays, information processing algorithms, standard message formats and procedures for analysis of alternatives. These specific methods are discussed in Section VI.

The process model presented in Figure 1 presents sixteen sequential steps in the initial planning phase. Initially, the commander and his principal staff officers have implicit conceptual alternatives in mind to accomplish the newly assigned mission. These conceptual alternatives are based upon doctrinal education, professional experience, recent information from personal observation of the force and environment and subjective evaluation of the capabilities of the force. The first three steps in the initial planning phase constitute a formal information gathering stage. The commander seeks to more clearly define the new mission and the condition of forces on the battlefield. The next four steps identify constraints which eliminate many potential alternatives before they are considered in detail. These alternatives are usually eliminated because of obvious shortcomings which suggest infeasibility. The next two steps involve the elaboration of remaining desirable alternatives. These alternatives are subjected to detailed analysis within the time constraint according to routine procedures. Finally, the commander selects the preferred alternative or course of action. The commander and the staff develop and implement that plan within the control cycle.

1. Tactical Mission Assigned

The tactical mission assignment provides information to the commander and his staff concerning an assigned objective and resources allocated to accomplish the mission. Roland Tiede and Lewis Leake stated that,

> "...Examination of combat mission statements disclosed that these were statements in three dimensions: The resources that could be expended, the time in which the mission was to be performed, and the area to be controlled. These constraints provide precise criteria for determining whether the mission was successfully achieved." [Ref. 17: p. 595]

Ideally, the commander seeks to accomplish the mission at minimal cost. A search for the best feasible alternative course of action begins at this point. In most cases, the uncertainty of the situation and the forces available suggest an unmanageable number of alternatives. The commander and his staff seek to reduce the alternatives rapidly by purposeful analysis of information. This information is contained in the force information base.

2. Force Information Base

The force information base is generated by reports and summaries transmitted from subordinate, higher, and adjacent units and by direct observation of the battlefield by the force commander. A recent briefing presented by United States Army Training and Doctrine Command classifies this information as technical, staff or command. [Ref. 18] Manual and automated techniques are employed to convert predominantly technical information into staff and command

information. The transformed information creates a perception of the battlefield. Standardized, automated reporting procedures within the force may reduce errors and inaccuracy within this information base.

3. Define Current State

The technical data base is manipulated to develop a snapshot of the battlefield. The goal is to achieve an accurate perception of the battlefield. Frequently, the commander's personal observations enhance the staff's perception of the combat environment. The current state is divided into friendly force size, activity and location, enemy force size, activity and location, and environment to include terrain and weather. The time constraint drives the rapid and accurate development of this perception. A directed search for additional information is expensive. Further, only relevant information should be presented. A technique developed from the theory presented in Sections II and III is to concentrate on maneuver unit assets, locations and activities and identification only of those relevant aspects of other technical subsystems which constrain or restrict maneuver options.

4. Current State Defined

The above process results in a common perception of the battlefield by the force commander and his staff. The quantifiable aspects of the units in the force have been integrated with the commander's subjective evaluation of

leadership, training and morale to determine unit capabilities and limitations. A general understanding of the level of uncertainty of enemy capabilities and intent has been achieved. Effects of weather and terrain on implicit alternatives have been developed.

5. Specify Criteria for Mission Success

The commander explicitly states the conditions which define mission success. Criteria include force strength at the point of mission completion, location and time. Guidance concerning priorities and tradeoffs is provided. The comparison of mission criteria or desired state to current state allows the formulation of acceptable trends over time. Further, thresholds are established for discrepancies between current and desired states which require command correction.

6. Desired State Defined

The criteria for mission success have been defined and a comparison may be performed to determine specific actions which are required to begin execution of the new mission. An additional benefit of this formalized process is a common perception of the battlefield. The commander provides guidance to insure unity of effort.

> "When explicit strategies are agreed (upon) during a planning cycle, there is a better chance that middle management's ad hoc decisions will be consistent with them." [Ref. 13: p. 142]

Potential conflicts which frequently result due to diverse perceptions of the new mission and current situation within the staff are reduced or eliminated. A common basis for evaluation of alternatives has been established.

7. Compare Function

The current and desired state are compared to determine the magnitude and direction of actions necessary to adjust to the new or changed mission. In Management System Dynamics, R.G. Coyle defines a discrepancy as the difference between current and desired levels of a system at a specific time. Levels of the force include location, task organization, weapon system strength, personnel strength, fuel, ammunition, leadership, morale and training. Coyle suggests that the magnitude of the discrepancy be examined to determine the force and magnitude of the corrective action necessary. [Ref. 10: p. 9] Major discrepancies require non-routine policy adjustments to include a change in task organization, operational concept, unit locations or control measures. The current plan being executed cannot be adjusted or adapted to new requirements or conditions. Minor adjustments are those changes which may be executed within the current operational plan. Minor adjustments are executed within the control cycle. Major adjustments requiring revision of the current plan or generation of a new operational plan are developed within the initial planning sequence.

8. Analyze Time Available

An analysis of mission, current and desired states in the time and location dimensions is executed. Total time available to transition from current activities to new mission activities is determined. This total time is divided into an initial planning phase, a reorganization phase, a movement phase and a consolidation phase. The initial planning phase is completed upon dissemination of a warning order which includes the new mission task organization, mission, operational concept, movement plan and security plan. The reorganization phase is concluded as maneuver and key support units initiate movement to designated initial fighting or attack positions. During the reorganization phase, subordinate units begin planning, briefing, rehearsals, replenishment and reorganization consistent with the warning order. The movement phase is completed as maneuver and key support units close on initial fighting and attack positions. Security is provided by reconnaissance, air defense and aviation elements. Mobility may be enhanced by appropriate allocation of engineer units. The consolidation phase is completed as the attack, movement to contact, delay or defense is initiated. This is the point at which execution of the new mission begins. During the consolidation phase, final plans are issued, briefings and rehearsals are conducted, positions are improved, supporting unit activities and adjacent unit plans are

coordinated. The generated timeline quantifies the time constraint imposed on the commander and staff to execute the initial planning sequence.

9. Analyze Weather and Terrain

Air Land Battle Doctrine prescribes time horizons for each echelon of the force. [Ref. 2: p. 7-15] Consistent with this time horizon, the commander and his staff analyze the effects of weather and terrain on the range of alternatives for both friendly and enemy forces.

10. Analyze Enemy Capabilities

Based on terrain and recent enemy activity, a projection is made of anticipated enemy activity consistent with the force's time horizon. The time horizon and terrain constraint enable bounding of the problem to a finite set of alternatives. A detailed understanding of enemy tactics based on doctrine and recent experience further enhance prediction.

11. Analyze Forces Available

The commander and staff execute a detailed examination of available maneuver forces and map these forces to terrain and enemy. An iterative process of maneuver allocation to the security mission, the main effort, supporting efforts, reserve and rear area protection clarifies the dimension of the mission and the potentially feasible alternatives. Special staff members representing technical subsystem commanders may observe this process.

The constraint of available maneuver forces is developed in detail.

12. Generate Alternative Courses of Action

The preceding analysis has enabled the commander and his staff to bound the problem and to identify possible solutions. Specific alternative maneuver schemes are developed which describe the phasing of each alternative, tentative task organization and timeline. In a sense, a dynamic programming problem has been analyzed. The binding constraints which bound the problem have been identified. The feasible region has been approximated. Again, special staff officers may monitor the process.

13. Analysis of Alternatives

The coordinating and special staff members analyze each alternative course of action with respect to their specific technical subsystem. Evaluation criteria include feasibility in the dimensions of time and subsystem resources available to support maneuver execution of each alternative. Infeasible alternatives are identified. Such alternatives cannot even be marginally supported by technical subsystems with available resources. Preference for feasible alternatives may be expressed if such information is requested by the force commander. Subsystems identified as critical to mission success receive the most thorough attention. This feasibility analysis explicitly recognizes the necessity of a systems approach to the

solution of the force command control problem. The approach suggested reduces the hazards of simplifying assumptions which may yield an infeasible solution. It recognizes Jay W. Forrester's belief that,

> "...Because we cannot mentally manage all the facets of a complex system at one time, we tend to break the system into pieces and draw conclusions separately from the subsystems. Such fragmentation fails to show how the subsystems interact." [Ref. 4: p. 3-3]

14. Commanders Decision and Detailed Guidance

The commander examines the feasible alternatives and employs his own criteria of risk, payoff, flexibility and initiative to select the preferred alternative to be executed. He provides clarifying guidance in the form of a specific scheme of maneuver and priority of support. He emphasizes those aspects of the operation which he considers critical to mission success. A loop may be invoked to return to generation of alternatives if available time permits.

15. Formulate Task Organization, Movement and Security Plan

The coordinating and special staff develop a task organization consistent with the commander's concept. Movement and security plans are generated based upon the task organization, time schedule and scheme of maneuver. An operations overlay with boundaries and control measures is also produced. The commander approves this plan and the warning order is issued. Advance notice may have been

provided to subordinate units, however this order enables reorganization, detailed planning and execution by subordinate units.

16. Formulate Maneuver, Support and Contingency Plans

Concurrent to subordinate unit planning and execution of the warning order, the coordinating and special staff formalize the maneuver, support and contingency plans. Technical subsystem commanders establish priorities and allocate resources to support the scheme of maneuver. Planning includes coordination with adjacent and higher units and monitoring of enemy activity and subordinate unit progress. The commander and selected members of his staff may move to a new location to execute effective command control during mission execution. The product of this step is the formal operations order with support plans detailing the execution of the assigned mission. The operations order is issued to subordinate commanders for execution.

The above sixteen steps are a sequential process which is performed by the brigade commander and his staff to formulate a sound operational plan. The initial planning phase is a specific process which reduces uncertainty and sets goals for the brigade within the constraints of available resources. The analysis of alternatives by all technical subsystems recognizes the interdependence of overall system performance on all components operating in concert. Within the control cycle, the explicit strategies

which have been developed can be examined for consistency in terms of friendly performance and enemy courses of action.

C. CONTROL CYCLE EXECUTION

Within the control cycle, battlefield information is analyzed to identify unacceptable conditions or trends which require corrective action. Trends in enemy activity and environmental conditions are monitored as well as the progress of friendly forces executing assigned missions. Coordination with adjacent units may generate requirements for adjustment of plans.

1. Start Control Cycle

The operational plan for execution of the mission is translated into a time schedule for each unit which projects the location and activity of the unit with respect to time. Predictions are made of critical unit levels to include weapon system strength, personnel strength, ammunition and fuel. This enables future comparison of unit situation or status reports to expectations. Each coordinating and special staff officer performs this task for his functional or technical subsystem. Critical levels of command concern are reported to the executive or operations officer.

2. Information Base

Higher, lower and adjacent units continue to submit routine and exception reports which constitute the force's

technical information base. Periodic reporting is a routine procedure in United States Army tactical units. The time interval between these reports is important as its duration affects the sensitivity and responsiveness of the control system. In Designing Organizations, Daniel Robey states, "...The longer the time span between measures, the greater the risk that the process will go out of control." [Ref. 19: p. 381] This assertion appears to be consistent with system dynamics theory and studies performed by Coyle and Forrester. The Maneuver Control System and other tactical automated systems make more frequent reporting technically feasible. In a maneuver brigade, company level units might be required to provide information updates every thirty minutes as well as immediate updates in critical situations of intense combat. In the recent past, the shortest reporting cycle using manual procedures was in the one hour range. Longer reporting cycles and manual processing procedures cause lags or delays in the control cycle which may reduce the effectiveness of the control system. Robey emphasizes that frequent reporting is more critical as the uncertainty of the situation increases. [Ref. 19: p. 399]

3. Update Current State

The technical information is transformed and aggregated to create a perception of the current friendly, enemy and environmental situation. Quantifiable levels of the force to include location, personnel strength, weapon

system strength, fuel, ammunition and current activity are generated. Intelligence summaries as well as unit reports clarify current and projected enemy activity as well as environmental conditions. Special staff officers update coordinating staff officers on the condition and progress of supporting units as they impact on execution of the combat mission. Information contained in the technical data base is accessed by technical subsystems command and control elements to assist them in the execution of their support functions.

4. Update Desired State

Revisions may be required to the desired state due to adjustments in the time schedule or task organization. The force may be exceeding its expectations and executing initiatives within the existing plan. The defined desired state must be consistent with the commander's goals and the realities of the tactical situation.

5. Compare Current and Desired States

The current levels of the force are compared with the projected trends to identify unacceptable or exceptional conditions. This examination includes an analysis of enemy activity with projections formulated in the initial planning sequence. The magnitude and direction of discrepancies are identified. The dimensions of the comparison include time, location, activity, personnel and weapon system strength. The nature of the discrepancies may be acceptable suggesting

no change to current plans. Unacceptable discrepancies require staff and leadership action to correct the situation or seize the opportunity which has developed.

6. Analyze Time Available

A projection of the discrepancy in the time dimension will indicate the time available to remedy the condition or seize the initiative. The commander first seeks to correct the condition internally with his current resources. The time analysis restricts the available alternatives and clarifies the feasible region. In many cases, the commander and his staff perform a tradeoff analysis to move conditions back into the acceptable range. The time available is that period in which the discrepancy can be corrected with current resources without major revision of the current plan. Standard preplanned responses are contained in contingency plans for reaction forces or counterattacks and may be invoked in this cycle.

7. Generate Alternatives

A creative process is executed similar to steps 11 and 12 in the initial planning sequence. Available resources are examined in the context of enemy and friendly situation as well as time available. Alternative courses of action to include reallocation of fire support, reinforcement, adjustment of boundaries, change in tactics or adjustment of expectations are generated.

8. Analyze Alternatives

Each alternative is examined in time, cost, risk and expected result dimensions. The alternatives must be consistent and contribute to execution of the force mission. Appropriate coordinating and special staff officers participate in this analysis and evaluation process. A feasibility estimate and rank ordering of alternatives results.

9. Commander's Decision and Guidance

The results of analysis are evaluated by the commander. Authority for implementation of minor adjustments may be delegated to coordinating staff officers. The commander selects the desired course of action or alternative and provides specific guidance to the staff for execution. Critical tasks are identified.

10. Formulate Fragmentary Order

The framework of the operations order is used to describe the adjustment or corrective action to be executed. It details the units involved and the plan for execution of the commander's decision. Annexes might include a new task organization, fire support allocation, or a revised operations overlay.

11. Higher, Lower, Adjacent Units Informed

The fragmentary order is transmitted to appropriate units. Units begin execution of the revised plan and report progress to the force commander's staff. Clarifying

instructions are issued as necessary. The control cycle continues as units perform the mission and report their status.

D. ADDITIONAL CONSIDERATIONS

This section has presented a general model of the command control process performed in United States Army tactical units. The model has evolved from examination of doctrinal materials from the United States Army Command and General Staff College, concurrent efforts by the analytic community at Fort Leavenworth, Kansas, (CACDA, CAORA, AMMO), and limited personal experience of the authors. In its present form it is a general model of the process. The process is adapted to specific missions, environments and operational types by individual users. This modeling process can aid effective decision making by increasing "...general understanding of the system..." and aiding "...in the development of alternative plans or courses of action to be considered..." as well as improved description of system requirements, constraints and interactions. [Ref. 20: p. 345] Force command control is a complex process. Jay W. Forrester asserts that,

> "...Model validity is a relative matter. The use of a ...model should be judged in comparison with the mental image or other abstract model which would be used instead." [Ref. 4: p. 3-4]

In the process of transition from a manual to an automated system, such a model is essential to define system

requirements in terms of tasks performed by machines and those performed by men. The general models contained in doctrinal publications lack the specificity necessary to design an effective man-machine system. The next two chapters will show that this model provides detail adequate for identification of specific procedures within the process which are tractable to automation.

V. MODEL INVESTIGATION

A. GENERAL

An early version of the process model described in Section III was exercised in a simulated brigade delay at the Battle Simulation Center, Fort Ord, California. This simulation was executed to examine and refine the process model, to develop potential analytic tools and to obtain sample data representative of the type of data which might be generated in actual combat. This data was subsequently examined for development of descriptive and predictive analytic tools which are presented in Section VI.

The First Battle Combat Simulation was selected as the vehicle for detailed analysis. First Battle provided a level of resolution to maneuver company level for U.S. forces which appeared to be adequate for requirements while meeting resource constraints of time and available player personnel. Pegasus, Dunn Kempf, and CAMMS exceeded resolution requirements and resource constraints unless major modifications were applied to normal rules and procedures. The simulation was executed during the month of August, 1983 by the authors with support from 1LT Geoffrey T. Megargee, the officer-in-charge of the Battle Simulation Center, MSG Stanley D. Kluth and SP4 Paul Salinas, both of the OPFOR element, HHC, 107th MI Battalion. The authors

planned and executed the brigade delay. The opposing forces were controlled by the soldiers cited above, employing tactics described in FM 100-2-1, Soviet Army Operations And Tactics. This section provides a detailed description of the simulation as well as methodologies employed in the process model.

B. SCENARIO

The standard scenario developed by the U.S. Army Command and General Staff College for the defensive tactics subcourse was employed with minor modifications. This scenario develops a U. S. Corps defense in the Fulda-Erfurt sector of the Federal Republic of Germany. The 10th (U.S.) Corps is opposed by the 24th Combined Arms Army (CAA) which is expected to attack with four motorized rifle divisions and two tank divisions. The 2nd Brigade, 23rd Armored Division is assigned the mission to delay east of the Fulda River for a period of six hours (H hour to H+6 hours) and to then defend in sector west of the Fulda River to defeat elements of two motorized rifle divisions. This mission is a modification of the standard scenario. This modification essentially requires the brigade to conduct a covering force operation and subsequent defense in sector to defeat elements of two motorized rifle divisions. A schematic of the brigade sector is shown as Figure 3. Phase lines and dimensions shown in this Figure will be referred to

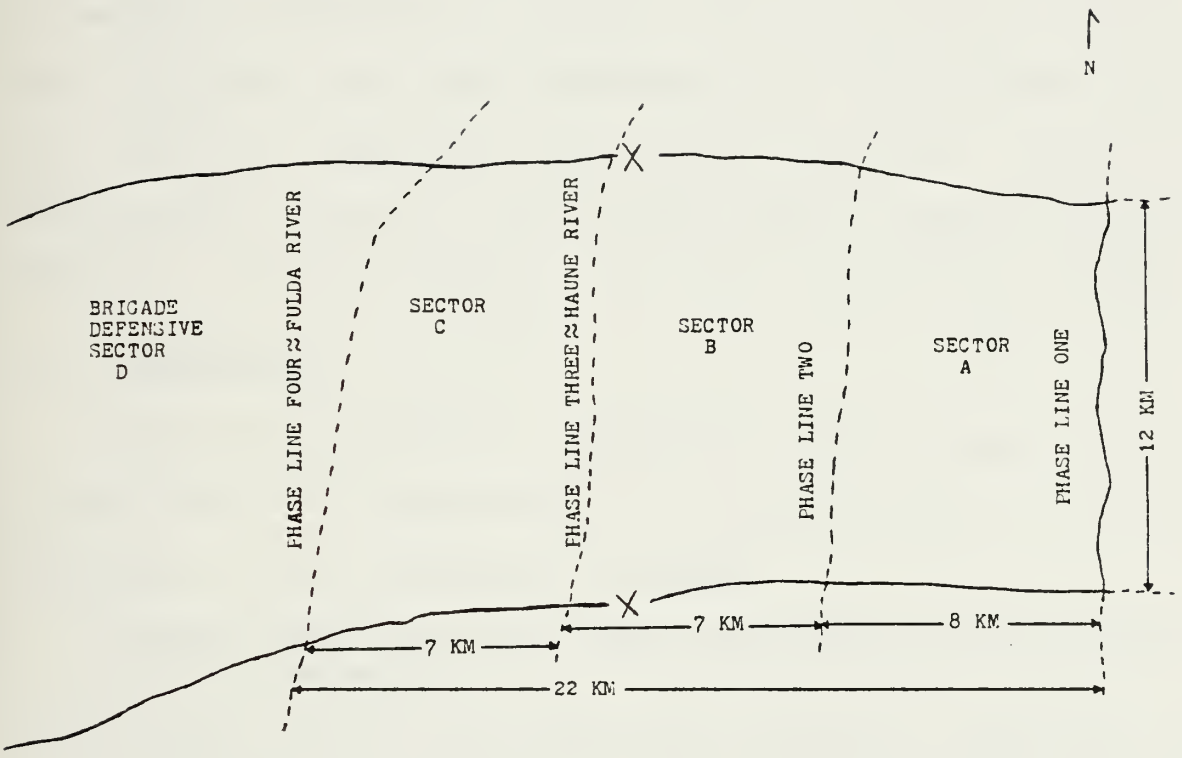

Figure 3. Brigade Sector Schematic

frequently in this analysis. It is suggested that the reader examine and conceptualize the dimensions before proceeding.

The brigade is designated as the main effort as a result of threat analysis by the division staff and the division commander's operational concept. This designation implies that adjacent units will coordinate and adjust their plans and execution consistent with the main effort. During the simulation, adjacent forces were fought by Captain Edward Negrelli, a fellow student at the Naval Postgraduate School.

C. ASSUMPTIONS

Some simplifying assumptions were made in the formulation and execution of the simulation. A brief statement of key assumptions follows:

-- Current operations have been restricted to conventional fire and maneuver.

-- Neither side has employed nuclear, chemical or biological weapons but both sides are capable of employing such weapons. A maximum of thirty minutes advance warning of such weapon employment by enemy forces may be provided.

-- The brigade is task organized with Division '86 maneuver forces consisting of two mechanized infantry battalions and two M1 tank battalions. Two field artillery battalions, an air defense battery, an engineer company, and a military intelligence detachment provide combat support. The combat service support package includes a maintenance company, a supply section, and a medical company. Other support allocations are standard to include signal, aviation and Air Force Liaison.

-- The brigade is currently located in an assembly area thirty kilometers from initial delay positions at phase line one.

-- The brigade has eight hours to occupy initial delay positions.

-- The mission has not been preplanned. However, unit leaders are familiar with the terrain in the operational area.

-- Units are at full strength with adequate training, leadership and good morale.

-- Final administrative and logistic actions to prepare for combat will be completed in two hours. Such actions include final fueling, ammunition distribution, ration issue, and emergency maintenance of critical weapon systems.

-- Local air parity exists. Risk of enemy air attack is moderate.

-- No significant enemy forces have crossed the international boundary. The enemy has the capability to insert a light infantry battalion in the brigade sector.

-- Divisional cavalry assets will constitute a rear area reaction force.

D. MISSION

The brigade has been assigned an initial mission to delay for a specified period of time and a subsequent mission to defend in sector. Such a mission definition provides the brigade commander with limited criteria for determining the minimum levels of force effectiveness which he must achieve to accomplish the initial and subsequent mission. The delay mission is executed to gain time to reduce uncertainty about the enemy course of action, to avoid decisive combat under unfavorable conditions of terrain and force dispositions, to draw the enemy into an unfavorable position and to inflict damage on the advance

elements of the attacking force. The delaying force's actions also may deny the attacker knowledge about the location of the main defensive effort. [Ref. 2: pp. 12-1 - 12-8] Essentially, the brigade is charged with the responsibility to execute a covering force operation in its assigned defensive sector.

E. ENTITIES AND ATTRIBUTES

The manual simulation for the brigade delay explicitly modeled the maneuver and fire support assets of the brigade. Company and battery level units were positioned and controlled on the game board. Levels of the units which were recorded during the course of the simulation included time, location with respect to the international boundary, weapon system strength, combat activity and a subjective net assessment. The time clock started with movement of enemy units across the international boundary. Weapon system strength tracked the number of tanks, infantry fighting vehicles and howitzers in each company or battery. Combat activity descriptors were none, light, moderate or heavy. Net assessment was a subjective percentage evaluation of current unit combat capability. These elements of information were developed from the format of the Commander's Report contained in the Maneuver Control System User's Guide. [Ref. 21] This technical information was recorded at the completion of each thirty minute game turn

to simulate the command reporting system. The communication process was not explicitly modeled.

F. SIMULATION OF THE DELAY

The delay was executed under the rules of First Battle. Game turns followed a general sequence of preplanned indirect fire by red, counterfire by blue, red initial movement, direct fire by blue, hasty attack by red (close combat), acceptance or refusal of close combat by blue, resolution of close combat, and final movement by both sides. Each game turn simulated thirty minutes of combat operations. The simulation stopped after five hours and thirty minutes of play with blue forces defending on the western bank of the Fulda River. A practice delay was executed to familiarize players with rules and procedures.

G. INITIAL PLAN FORMULATION

1. General

The process model described in Section IV was employed to formulate the initial plan and to execute the control cycle for the delay portion of the brigade mission. The examination was restricted to the commander's and operations officer's perspectives due to player limitations. The following subsections provide a brief description of the actions performed for each step of the process.

2. Define Current State

The current state was defined from the initial information base. This information base consists of data which already exists in the system from previous operations and data provided from the division operations order. Data in the information base is categorized as friendly force information, information about the enemy and common information. Each category is described in the following subsections.

a. Friendly Force Information

Friendly force information is data which describes the size, location and activity of higher, lower and adjacent units in the force. Based on the new task organization, the brigade staff seeks updates from all assigned and attached units in accordance with prescribed reporting procedures. For the simulation, the only units explicitly reporting to the brigade operations center were the four maneuver battalions and two artillery battalions. The situation map was updated with unit locations, boundaries and control measures imposed by the new mission. Activity and location of immediate adjacent units was also plotted.

The principal attributes of friendly subordinate maneuver units which were monitored in the simulation were location and weapon system strength. The same attributes were monitored for the supporting artillery units. The data

generated by company situation reports is technical detailed information. This data is aggregated at battalion level to provide a picture of the battalion's combat power. Subordinate unit data concerning location and activity was transformed to define a front line trace. In this paper, such aggregated data will be referred to as staff or command information. The primary difference between the two types is the level of detail contained in the information. In most cases, for any existing item of command information, there is an available staff information file derived from technical data which can be examined by the commander to gain further insight into the condition.

In terms of the theory of combat power presented in Section III, the basic measure of combat power in the maneuver company is the number of fully manned major weapon systems. For a heavy company/team, the major weapon systems are the tank and the infantry fighting vehicle with crews. The mix of these weapons is indicated by designation of the company/team as mechanized, armor or balanced.

In his book, On The Banks Of The Suez, Major General Avraham Adan provides a detailed account of the actions of the Israeli Armored Division which he commanded during the Arab-Israeli War of October, 1973. His book supports the above measure of combat power as well as the fact that continuous cross leveling of men to weapon systems is executed in the company/team in combat. [Ref. 22] A

mismatch of personnel and weapon systems reduces the combat power of the company/team. The company leadership continuously strives to minimize this effect by cross leveling. Based on this methodology, the company commander reports his actual combat condition by reporting the number of fully manned major weapon systems currently on hand and the binding constraint if a mismatch develops between personnel and weapon systems. As combat continues, fuel, ammunition, leadership, maintenance and fatigue may constrain combat power but assuming that these conditions are managed effectively, the primary index of maneuver combat power is manning of major weapon systems. The corresponding status report submitted by the company/team is the basis for staff policies and leadership decisions for the maneuver force.

A similar argument is made for the fire support technical subsystem. Mortar, tube artillery and missile systems are the basic components of combat power which are manned to support the maneuver force. Manning of the control systems which link these systems to the maneuver force is implied. Similar approaches may be adapted in some manner to the other technical subsystems of the force. These aggregated subsystem descriptions are developed by the brigade coordinating staff. They provide the commander with an integrated definition of the current condition of the friendly force. This definition is refined by the

commander's experience and personal evaluation of unit leadership and battlefield conditions. In addition to definition of the current state, the periodic reports tracked over time enable the brigade commander and his staff to identify trends in subordinate units which require changes or adjustments. Specific examples of current state representation and trend analysis are presented in Section VI.

Using this methodology, the four maneuver battalions assigned to the brigade were defined in terms of fully manned weapon systems. Two were pure armor battalions at 100% strength and two were pure mechanized infantry at 100% strength. The two medium artillery battalions were also at 100% strength.

b. Enemy Force Information

A similar methodology was applied to the enemy force. However, during the simulation, intelligence gathering was not explicitly modeled except for intelligence obtained from subordinate units engaged in combat. The enemy force current state may be developed in a similar manner to the friendly force techniques described above. The brigade intelligence system strives to develop an accurate picture of the array of enemy forces which oppose the brigade. Employing techniques suggested by AirLand Battle Doctrine, the enemy force array is divided into threat sectors based on time horizons. Analysis of

identified force arrays may provide a measure of the relative combat power of opposing forces in the brigade area of interest. This is the sector of immediate concern to the brigade commander. By further tracking the change in strength and activity of the enemy force in this sector, the brigade intelligence officer may be able to identify a pattern which confirms a specific enemy course of action from the several possible alternatives. In this manner, the intelligence system may employ quantitative techniques to reduce uncertainty about the enemy situation.

Research material reviewed for this thesis indicates that the intelligence community has made significant progress in this area. Intelligence Preparation of the Battlefield (IPB) techniques described in FM 100-5 are a key example. In a sense, each technical subsystem of the brigade prepares the battlefield with respect to the enemy threat to plan the execution of its portion of the brigade operation. Due to player personnel limitations, intelligence gathering analytic techniques were not employed in the delay simulation. This area might be examined in detail as a follow-on study which uses the theoretical framework of this thesis to develop specific techniques.

c. Common Information

Common information includes information about the environment of combat in the brigade sector. Time horizons are employed to project weather, terrain and

visibility conditions. The brigade immediate area of interest consisting of the covering force sector and the main defensive sector was divided into subsections for detailed analysis. The basis for phase line divisions was the identification of a basic change in the nature or trafficability of terrain or a natural terrain feature which transits the sector. In Figure 3, for example, Sector A is open terrain while Sector B is a more forested area. Phase Line Three in the same figure coincides with the Haune River. Characterization of the terrain in terms of mobility, intervisibility cover and concealment enabled matching of force types (armor, mechanized infantry or balanced) to the terrain. The phase lines identify sectors in which transition problems might be expected as, for example, the case in which a pure armor unit transitions from open high mobility terrain to densely forested terrain with restricted fields of fire and mobility. The principal tool employed for this analysis was the standard military map.

Another common item of information of importance is the activity and control of the indigenous population. This information may indicate potential for force augmentation, constraints on road trafficability and special security requirements.

The data elements described above are aggregated by the brigade coordinating staff to provide a command perception of the current situation in terms of the friendly force, enemy force and environment. In the past, these perceptions were presented to the commander for analysis in a manually prepared staff briefing. Automation of this process may reduce error and increase the responsiveness of the staff to the commander's decision information requirements. A significant reduction in decision cycle time may be achieved while appropriate design of the information products may enhance the accuracy of the commander's perception of the current state.

At this point in the process, the commander and operations officer have reviewed the current condition of friendly forces, opposing enemy forces and the environment in the context of the newly assigned mission. Available maneuver and fire support resources for the delay were identified. Ammunition, fuel, personnel and leadership did not appear to be limiting constraints for execution of the delay.

3. Specify Criteria For Mission Success

During this step, the newly assigned mission was analyzed to determine criteria which quantify mission success. The three dimensions of these criteria for the maneuver (terrain controlling) forces were time, terrain and force level in terms of fully manned major combat systems.

The concept of tracking force levels in terms of fully manned combat systems is expected to be controversial. However, it is a true representation of the net combat power of the maneuver force and is the basis of the commander's decisions concerning immediate future operations whether it is explicitly stated or not. General Adan's description of his decisions in combat support this assertion. [Ref. 22]

The brigade mission was defined in two distinct phases. The first phase required the brigade to delay east of the Fulda River for six hours after the enemy initiated an attack across the international boundary. Figure 3 dimensions display this as a requirement to delay over a distance of twenty-two kilometers for a period of six hours. The end force level goal established for this phase was for the brigade to attain at least sixty percent of authorized strength of fully manned major ground combat systems. This is a minimum goal for the completion of the delay in the dimensions of time (six hours), terrain (approximately twenty-two kilometers) and force level (sixty percent of authorized fully manned major combat systems). This goal becomes the starting condition for the second phase of the brigade mission; the defense in sector operation. In the simulation, the brigade operation was only executed for the delay. Though not examined in detail, it appears that criteria may be more difficult to quantify for a sector defense. This definition of the desired goals for the

brigade delay in terms of quantifiable criteria was the basis for comparing alternatives later in the process. The delay end condition criteria was also projected forward in time to the starting conditions by imposing corresponding goals on each phase line in the covering force area. At each phase line, the corresponding goal in the dimensions of time and force levels was recorded on the map to enable comparison of the current and desired state. This discrete technique of periodic comparison may be executed more frequently using automated continuous projections which are explained in detail in Section VI.

4. Compare Current Versus Desired State

This step is an explicit comparison of the current and desired state to determine the magnitude of the discrepancy which exists. In the delay simulation, the brigade was in an assembly area. Major troop movements, task organization and tactical planning were required to execute the newly assigned mission. A decision was made by the commander to execute a formal planning process to formulate the initial plan. Reorganization and relocation of forces was required to execute a significantly different scheme of maneuver and plan for support.

5. Analyze Time Available

The commander and operations officer projected a time schedule for the non-concurrent phases of the operation. This was executed in a backward planning

sequence beginning with the defense in Sector from H+6 to H+12 hours, delay from H to H+6 hours, occupation and improvement of initial delay positions from H-3 to H hour, movement to initial delay positions from H-5 to H-3 hours, subordinate unit reorganization from H-6 to H-5 hours and formulation of the warning order from H-8 to H-6 hours. This estimate clarified the time available for initial planning and the general sequence of non-concurrent actions which were required for maneuver units to accomplish the mission.

6. Analyze Weather And Terrain In The Operational Area

The common information in the information base was examined to identify constraints on friendly and enemy courses of action. Potential primary and secondary avenues of approach into the brigade sector were identified. A particular aspect of terrain for the delay which was examined was the effect of terrain and obstacles on the mobility and flexibility of the delaying force. Delay channels and their flow capacities were identified. Delay Sector C was extremely restrictive to rearward movement of forces. These constraints were carried forward to the generation of alternatives. Simulated weather was clear summer daylight.

7. Analyze Enemy Capabilities

As stated earlier, the enemy situation was treated as highly uncertain for the simulation. The division

operations order indicated at least an enemy division attacking in the brigade sector. The exact location and size of enemy forces was not known. An attack across the international border was expected no earlier than eight hours from the receipt of the division operations order. The division order indicated that the enemy main effort was expected in the brigade sector. Terrain and uncertainty of the enemy force dispositions suggested relatively uniform lateral distribution of defending forces in the delay sector.

8. Analyze Forces Available To Execute The Mission

The information base was queried to examine the composition of maneuver forces available in terms of leadership and major combat systems. Critical supporting systems were also quickly reviewed to determine support capabilities and limitations. Fire support, engineer and air defense were considered to be at full strength and adequate for the mission. Principal constraints identified were time and available maneuver forces.

9. Generate Alternative Courses Of Action

> "Delay is a mission that requires a unit to trade space for time without losing freedom of maneuver, risking penetration, or being bypassed. The delaying force may attack, defend, ambush, raid or use any other tactic necessary to accomplish the mission." [Ref. 23: p. 2-34]

The doctrinal basis for alternatives was supplemented by the division operation order. Continued retention of terrain in

the delay sector was not required. The covering force mission implies the goal to inflict heavy casualties on the leading elements of the attacking force while preserving the strength of the delaying force for later employment in the defense in sector. A technique which was employed was to generate alternatives which successively increased the forward concentration of maneuver forces in the delay sector. This technique involved the allocation of appropriate type forces to terrain. Sector A favored employment of armor units, Sector B favored employment of balanced units and Sector C and D favored mechanized infantry units. All courses of action were developed with a subsequent plan for a forward defense along the Fulda River. The Fulda River was considered to be decisive terrain in the simulation. Course of Action I deployed an armor battalion in Sector A, two balanced battalions in Sector B and a mechanized infantry battalion in reserve consolidating defensive positions along Phase Line Four (Fulda River). Course of Action II deployed two armor battalions in Sector A, and two mechanized infantry battalions in Sector C to execute a successive delay. Course of Action III deployed three balanced battalions in Sector A and a balanced battalion in Sector C as a reserve. Divisional cavalry assets were considered adequate for rear area protection. Basically, each course of action allocated maneuver forces to direct combat, reserves and rear area security.

10. Analysis Of Alternatives

In August, 1983, the specific analytic tools for alternative analysis which are discussed in Section VI had not been developed. They are a product of the simulation. The basic criteria used for analysis of alternatives in the simulation were adequate coverage of terrain, supportability and flexibility. The restrictive terrain in Sector C was a major factor in alternative analysis. It appeared that this terrain would not only slow the advance of the attacking force but would also complicate delay execution if the brigade's forces were concentrated forward initially. Forward concentration would also reduce the resources available for preparation of the main defensive positions along the Fulda River. This analysis led to the elimination of Courses of Action II and III.

11. Commander's Decision And Detailed Guidance

Based on the criteria of adequate coverage, supportability and flexibility, Course of Action I was selected as the most desirable alternative. The commander's guidance was to execute the delay in three phases. Phase I involved the delay battle fought by the Armor Battalion in Sector A from H to H+2 hours. Phase II consisted of a passage of lines at Phase Line two by the delaying armor battalion through the two balanced task forces. Phase III was the execution of a delay by the two balanced task forces in Sectors C and D from H+2 to H+6 hours. The commander's

guidance included emphasis on forward positioning of fire support assets and the necessity for continuous lateral coordination with adjacent maneuver units during the delay. Priority of support was initially to the armor battalion and then to the balanced task force in the southern portion of the brigade sector after the passage of lines. After the passage of lines, the armor battalion would move to the Haune River area to serve as the brigade reserve. The mission of the mechanized infantry battalion at Phase Line Four was to prepare the main defensive positions and to serve as the rear area reaction force.

12. Formulate Task Organization

Based on the scheme of maneuver, forces were task organized to execute the assigned mission. Maneuver reorganization sought to minimize changes in the current configuration of task forces. A similar approach was employed for allocation of support. This was explicitly executed for maneuver and fire support but implicit for other subsystems such as engineer, air defense and signal.

13. Formulate Movement And Security Plan

The movement and security plans were developed to schedule and coordinate the movement of the brigade from the assembly area to initial positions dictated by the commander's guidance. The movement plan indicated routes, time schedules and control points for each subordinate unit.

The security plan provided for horizontal security using reconnaissance forces and vertical security using air defense assets along movement routes. This information was provided to subordinate units to begin execution of the new mission.

14. Formulate Maneuver, Support And Contingency Plans

This step involves the development of detailed instructions and overlays which constitute the formal brigade operations order with annexes. This step in the sequence was not formally executed for the simulation. The operations plan is formulated by the brigade staff and transmitted to subordinate units for detailed planning and execution. As units begin execution of the new mission, the brigade command control system begins execution of the control cycle phase of the command control process.

H. CONTROL CYCLE

The control cycle for the brigade delay was based on periodic updating of the information reported by subordinate units and the commander's observation of the battlefield. This information was aggregated to gain understanding of the current state of friendly and enemy forces in the dimensions of time, location, activity and weapon systems strength. These conditions were then compared with the goal established for the force during the initial planning phase to determine if an unacceptable discrepancy existed. The

comparison also sought situations in which the force was far exceeding goals and might be able to seize the initiative by execution of a limited counterattack or ambush. First Battle did not seem to effectively model these potentially high payoff situations. The following subsections describe control cycle execution for the simulated delay.

1. Update Current State

Based on the results of each thirty minute game turn, the time, location, activity and weapon system strength of each maneuver company and field artillery battery was recorded. A front line trace approximation was obtained from the mapboard. Task force and brigade strengths were aggregated from company reports. The result was a descriptive status of the brigade in terms of time, location, activity and weapon system strength.

2. Update Desired State

The desired state was the goal for the brigade in the dimensions of time, location and weapon system strength. During the delay simulation, successive goals were established for each delay phase line. As the brigade front line trace crossed each phase line, a comparison could be made between the current and desired state. Initially, the desired state for maneuver forces was fixed for each phase line but later alternative generations (fragmentary orders) required the commander to make minor adjustments to the desired state.

3. Compare Current And Desired State

Using the criteria of location, time and weapon system strength, the operations officer was able to monitor and evaluate mission execution. The commander was advised of mission progress and situations which required tradeoff analysis. Quite frequently, the brigade was on or ahead of its time schedule with respect to terrain but was losing weapon systems in combat at a rate greater than anticipated. Such a condition suggested a change in maneuver tactics or engagement techniques. These conflicts between the current and desired state required adjustments to the plan. When no adjustment was required, appropriate units were advised.

4. Analyze Time Available

In contrast to the initial planning sequence, this time analysis is based on the trend which has developed during the current operation. The commander and the operations officer examined an unacceptable condition to determine the time remaining before the unacceptable condition could no longer be corrected with resources organic to the brigade. This was a subjective evaluation in the simulated delay which may be enhanced by trend analysis techniques presented in Section VI. The result of this time analysis was a timeline which identified time available for planning, movement and execution.

5. Generate Alternatives

The first step in alternative generation was establishment of a cause-and-effect relationship for the identified discrepancy. In the cases of excessive losses and force time schedules exceeded, the brigade elements were accepting too much close combat or decisive engagement. This is an obvious simplification in the simulation but reflects an example of the inferences which may be drawn by the brigade commander and his staff. Other real causes could be misallocation of fire support or engineer countermobility resources. The cause-and-effect analysis and time available were the constrained basis for developing feasible alternatives to correct discrepancies. The commander searched his force assets and experience for adjustments to correct the discrepancy.

The concept of cause-and-effect analysis raises some key issues when compared with the concept of "...turning inside the enemy's decision cycle." [Ref. 24: p. 2] During the simulation, the defender's method was to formulate and execute a simple, sound and flexible tactical plan which integrated maneuver and fire support to achieve maximum combat power over time. During the first two hours of the simulation, this plan was followed explicitly to identify trends in a stable situation. These initial trends enabled the commander to predict the future condition of the brigade if current operational policies continued. This prediction

was the basis for policy adjustments. In contrast, the "turning inside the enemy's decision cycle" concept frustrates attempts at cause-and-effect analysis and threatens system stability. If this technique had been employed, less analysis of the effects of subsystem interaction could have been performed to suggest alternative policies for resource allocation. The authors believe that this approach to tactical decisionmaking in a complex combat system contributes to system instability, dangerous oscillation and may have disastrous consequences over time.

Some alternatives which might be generated in actual combat are changes to personnel and crew replacement procedures, changes in electronic warfare priorities, changes in tactics employed by maneuver combat systems and units, changes in the allocation of fire support assets, changes in priorities of engineer tasks, changes in the composition or location of maintenance contact teams and changes in the type or quantity of ammunition supplied to combatants. Most of these alternatives could not be examined or applied in the First Battle Simulation. The primary alternative which was examined and invoked was a change in maneuver tactics.

6. Analyze Alternatives

In actual combat, this analysis would be performed by the commander and appropriate members of his coordinating staff within the time constraint. During the simulation,

the limitations of the First Battle model and player personnel restricted the range of alternatives and the detail of analysis. Section VI suggests some techniques which might be employed for alternative analysis to correct deficiencies in the current execution of the plan.

7. Commander's Decision And Guidance

This step is similar to the corresponding step in the initial planning process. During the simulation, the primary change in guidance was to avoid decisive engagement by attacking forces. Whenever a close combat situation developed, the brigade commander was directly involved in the decision to fight or disengage. Each case was examined in detail in relation to the condition of adjacent delaying units and the strength of the force in danger.

8. Formulate Fragmentary Order

During the simulation, fragmentary order formulation was executed by a brief analysis and discussion following each game turn which set the adjusted tactics and general plan for the subsequent game turn. This action corresponds to the feedback and adjustments to plan execution which would be directed by the brigade commander and his staff.

I. DISCUSSION OF THE SIMULATION

This cyclical process was repeated for each game turn of the First Battle simulation of the brigade delay. The simulation ended after five hours and thirty minutes of

simulated combat with the brigade weapon system strength at approximately fifty five percent. The brigade was positioned for the defense in sector at the west bank of the Fulda River.

The delay simulation appeared to support the general process model described in Section IV. The following section presents data obtained from the simulation to demonstrate specific analytic tools which might be employed by the commander and his staff to achieve effective force command control.

VI. ANALYTIC TECHNIQUES

A. GENERAL

The preceding sections of this thesis have developed a framework to define the force command control system. The brigade commander and his staff accomplish force integration of the technical subsystems in the force as they execute the force command control process. Each technical subsystem has its own technical command control system which executes intensive management of subsystem assets to support the force operations plan. The focus of all other technical subsystems is protection and support of the maneuver technical subsystem as it prepares for, executes and recovers from combat operations. The objective of the force is to defeat the enemy force while preserving its own capability to continue the fight. The combat force achieves this by synchronization or peaking of combat power at the critical place and time on the battlefield. [Ref. 2: p. 2-3] The mechanism for synchronization is the force command control process.

Sections IV and V of this thesis specified and examined a model of the force command control process for a heavy brigade executing a delay in a European scenario. This section suggests specific analytic techniques which might be employed by the brigade command control system to achieve

synchronization on the AirLand Battlefield. The techniques are presented in sequence as they might be employed in the process model presented in Section IV. Data obtained from the simulation described in Section V provide examples of the techniques. While the focus of these techniques is on description and prediction of the maneuver force condition, similar techniques might be developed and employed for each of the other technical subsystems.

B. CONSTRAINTS ON ANALYTIC TECHNIQUES

The techniques presented in this section depend on automated support within the command control system. The first automated support component is an effective communications system within the maneuver force and across technical subsystems. Conceptually the communications system would contain digital data links which automatically encode, transmit and decode manually entered company level report data. The second automated support component is the Maneuver Control System (MCS) or other computer system which automatically stores, aggregates and may evaluate data received from subordinate units. The third automated support component is a remote terminal device which is linked to the MCS data base. This terminal is operated by the trained personnel of the force headquarters to develop force information, perform analysis, prepare plans and orders and monitor execution of plans and orders. The

analytic techniques presented in this section may require substantial modification for manual execution in the absence of the above automated system components.

C. DATA SOURCES FOR FORCE INFORMATION

The force information base is initialized and updated from standardized reports. For maneuver units, these reports are specified in the Maneuver Control System User's Guide. Similar standard reports are provided to the force command control element by the other technical subsystems of the force. These subsystem reports are compiled by the special and coordinating staff officers of the brigade headquarters element. The intelligence section initializes and updates the enemy and environmental situation while the operations officer provides the corresponding information for the friendly forces.

An additional component of the data base which is proposed in this section is a table of parameters for use in outcome predictions. These parameters are dependent on terrain, level of combat and type of force employed. The parameters would specify loss rates for major weapon systems, fuel consumption rates and ammunition consumption rates. The parameters might be obtained from combat simulations and could be improved by analysis of actual combat data. These parametric techniques are proposed as a

supplement to command and staff experience estimates of probable outcomes.

In the case of mechanized infantry and armor units, the Maneuver Control System Commander's Report quantifies the maneuver unit condition in terms of the number of fully manned tanks, the number of fully manned infantry fighting vehicles, unit location, time, current level and type of combat activity, and aggregate fuel and ammunition status. The parametric analysis proposed above suggests that each measurable level of the unit may be modeled over time, terrain and projected combat to predict the future condition of the unit. This approach enables relative comparison of alternatives and may suggest specific policies for refueling or rearming for a specific alternative.

This proposal recognizes the qualitative aspects of a unit's condition. Such aspects include unit morale, leadership, training, cohesiveness and fatigue. The commander and staff perform this qualitative analysis and merge the results with the quantitative techniques to arrive at the best decision. At a minimum, the quantitative approach may identify undesirable time, distance and force relationships which are not intuitively obvious to the commander.

D. ANALYTICS IN THE INITIAL PLANNING SEQUENCE

The Initial Planning Process model presented as Figure 4 has been coded with numbers to identify specific steps in the process which have potential for application of quantitative analysis. The proposed quantitative techniques use data in the information base, input from the brigade decision group and combat parameters to assist the brigade decision group in the planning, execution and control of combat operations. This discussion is limited primarily to the actions of the brigade commander, intelligence officer and operations officer. Applications for other members of the coordinating and special staff are discussed only as they contribute to the commander's decision process. The decision group employs these quantitative tools as well as qualitative judgment to execute the command control process. The following subsections correspond numerically to the specific numbered steps of the process model in Figure 4. Each subsection elaborates specific quantitative tools which might be employed within the respective step of the process.

1. Define Current State

The procedures employed in this step of the process consist primarily of aggregated descriptions of the current situation using maps, graphical displays and text supplements to provide clarification to graphs. The techniques presented are representative of the procedures which are currently being used within VII (U.S.) Corps in

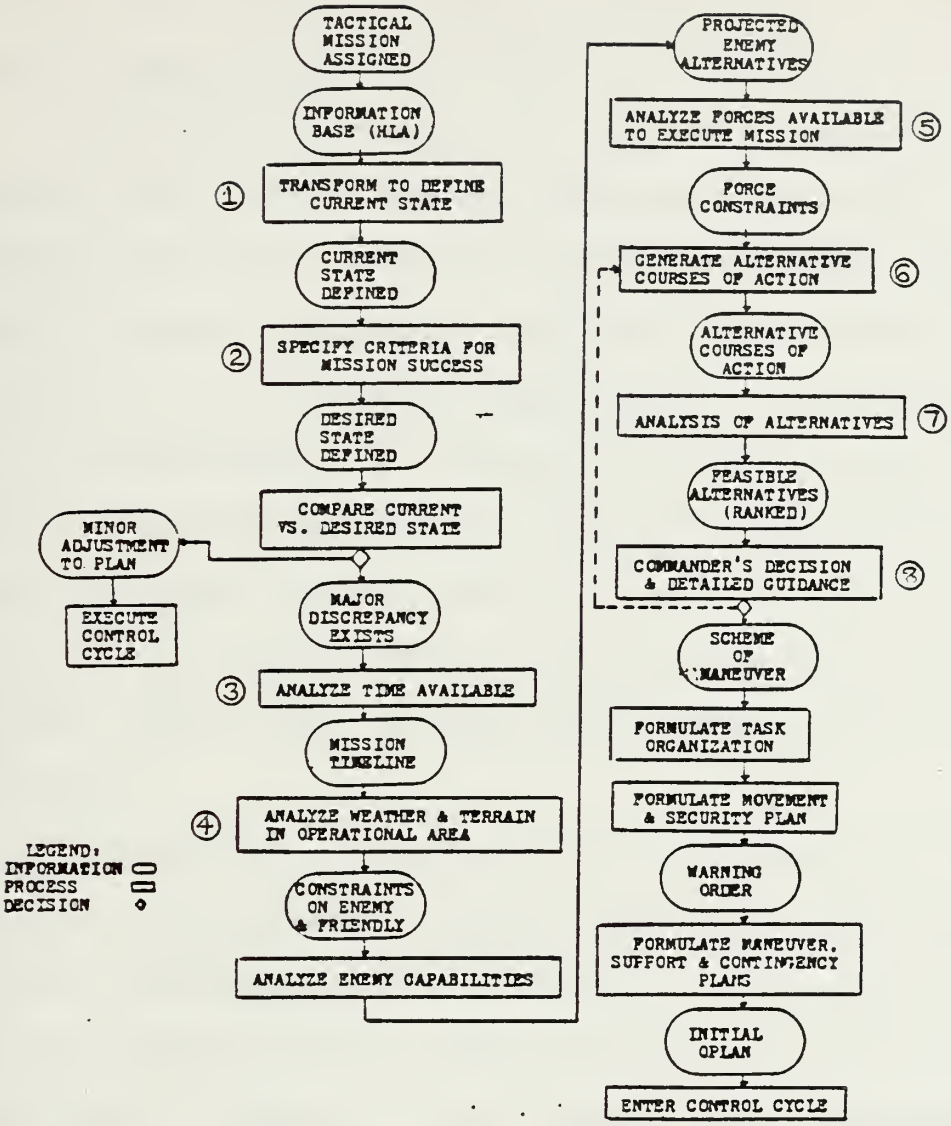

Figure 4. Initial Planning Process Model (Numbered)

Germany. The VII (U.S.) Corps procedures were demonstrated to the authors during a visit to CACDA at Fort Leavenworth, Kansas in May, 1983.

The first procedure is detailed examination of an updated map display which identifies the most recently reported locations of major friendly and enemy units. The display employs standard military symbols and control measures to depict current force dispositions. This display may be presented on a terminal as well as on a standard manually posted map display. The MCS literature suggests that a "plasma" device may be developed to replace the manually posted map board. The map analysis provides the command group with a gross description of the current situation.

This gross description is refined by a standard sequence of information graphics and text supplements which provide the commander with specific information about the friendly force status, enemy situation and environmental conditions. Figure 5 is an example of a presentation of current force status. This graph is based on each technical subsystem commander's evaluation of his subsystem's capability to support the force. Specific subsystem limitations are identified in a text supplement. Figure 6 is an example of an underlying detailed description of the current status of maneuver battalions which is aggregated to describe the brigade maneuver condition. This graphic

CURRENT FORCE STATUS
SITUATION AS OF TIME_____

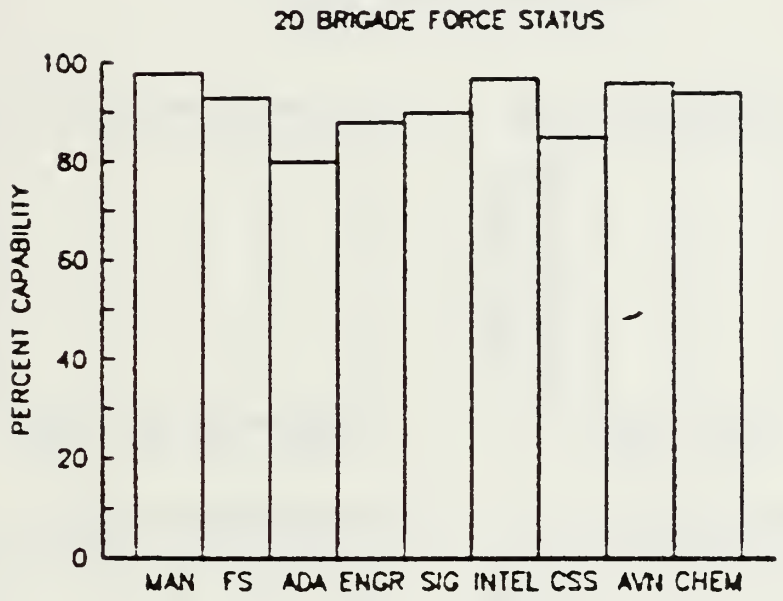

Figure 5. Current Force Status

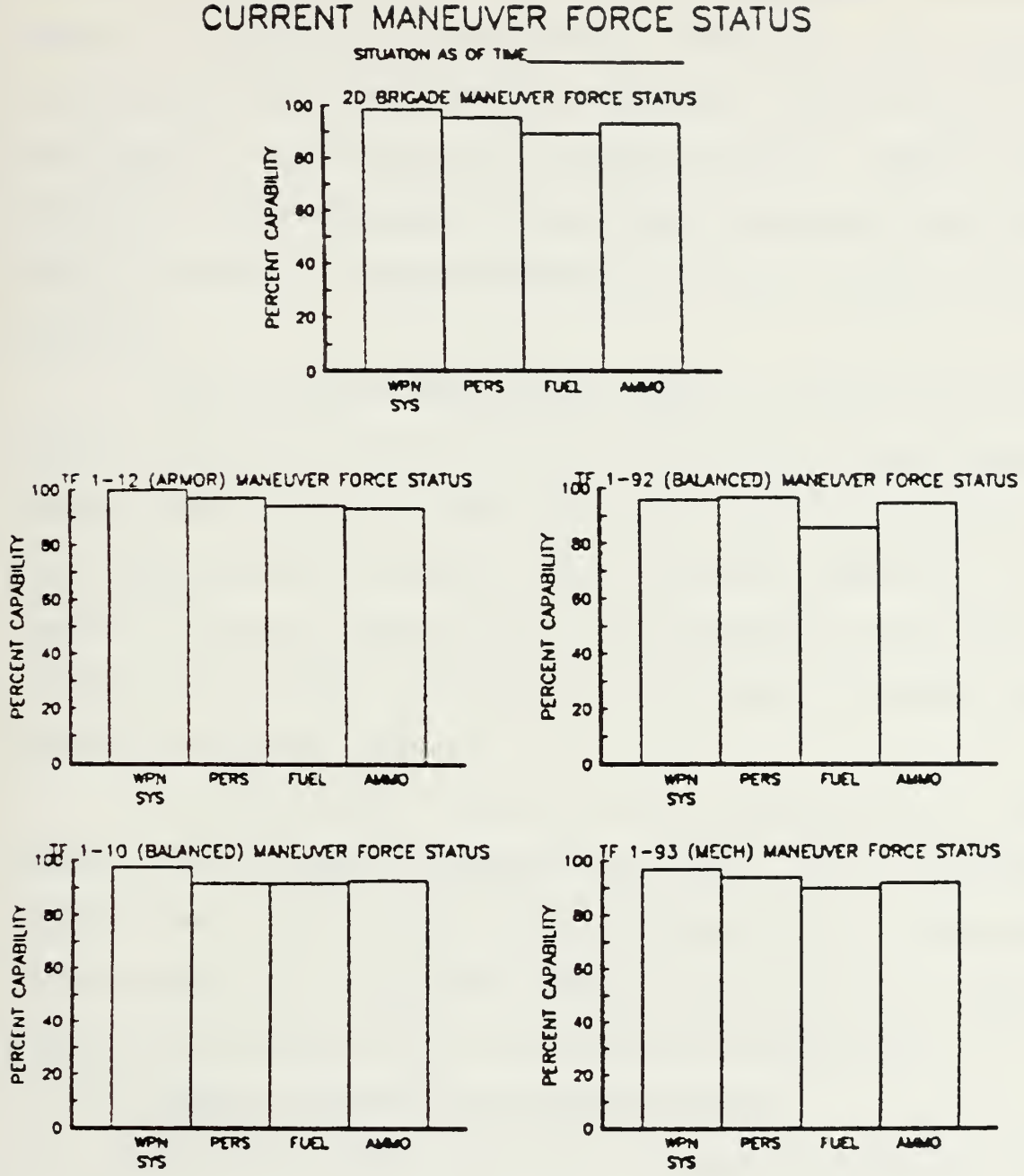

Figure 6. Current Maneuver Status

display is developed by the brigade operations officer. Figure 7 is a similar display which represents the current condition of the fire support subsystem. This display is developed by the brigade fire support officer. Appropriate graphical representations of the other technical subsystems would complete a command update of the friendly force situation.

The brigade intelligence officer might formulate similar descriptions of the enemy force from intelligence reports and analysis. Such analysis might include force ratio descriptions of enemy versus friendly maneuver, fire support or other capabilities. The brigade intelligence officer also provides a summary of the impact of weather and terrain on the new mission.

The commander reviews this information in the context of the newly assigned mission. He is seeking information to limit his implicit alternatives by detailed examination of friendly force limitations, enemy capabilities and predicted environmental conditions.

2. Specify Criteria for Mission Success

The commander executes a rapid analysis of the assigned mission in the dimensions of time, terrain and resources consumed. This is a goal setting process achieved by examination of the mission. "...Forward-backward planning is carried out within two limits. One is fixed in the present by the actors and available resources; the other

CURRENT FIRE SUPPORT STATUS
SITUATION AS OF TIME_____

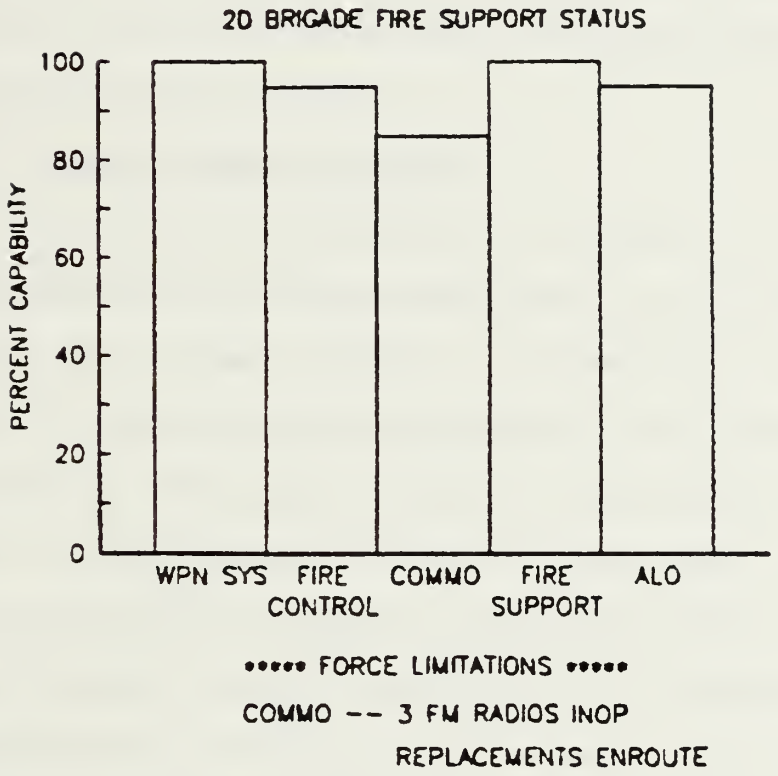

Figure 7. Current Fire Support Status

is fixed in the future by the desired objectives." [Ref. 25: p. 124] The commander specifies the goals of the force in terms of location, time and maneuver strength consistent with the force level planning horizon. For the brigade, the planning horizon might be twelve hours from the present. This specified goal establishes a basis for development and evaluation of alternatives. Techniques employed in this step are a blend of experience, time-distance computations and brief terrain analysis.

3. Analyze Time Available

A backplanning sequence is executed to identify the non-concurrent activities which must be performed to begin execution of the new mission. A prompting system might be invoked to assist in this analysis. This prompt would be dependent on the type mission to be performed and might invoke a time-versus- distance algorithm to determine expected movement time for brigade displacement. The critical output of this analysis is a suspense time for dissemination of the warning order. The analysis also enhances the understanding by the commander and key staff of critical activities which must be performed to initiate execution of the new mission.

4. Analyze Weather and Terrain

Several tools might be employed in this step using a limited terrain model. The model might be a graphic display which presents color coding of terrain mobility in the

brigade sector. This display would clarify avenues of approach into the brigade sector and might also identify key obstacles such as rivers or densely forested areas. For the delay mission, this analysis included characterization of the terrain in terms of the type maneuver force which was best suited for employment in each sector. Figure 8 shows a dimensional analysis of the delay terrain divided into sectors. This schematic was used for the delay simulation to formulate alternatives which allocated appropriate forces to terrain and provided adequate lateral coverage. The diagram also facilitated time versus distance computations.

5. Analyze Forces Available

During this step in the process, the brigade commander and operations officer concentrate on the allocation of maneuver forces to the missions of direct combat, reserves and rear area protection. The commander reviews the current composition of available maneuver battalions with respect to the newly assigned mission and terrain. This analysis also involves an evaluation of the current command control capability of each maneuver battalion to determine if cross-leveling or other reorganization is required.

6. Generate Alternatives

The commander and operations officer generate courses of action which successively increase the allocation of maneuver forces to direct combat and corresponding

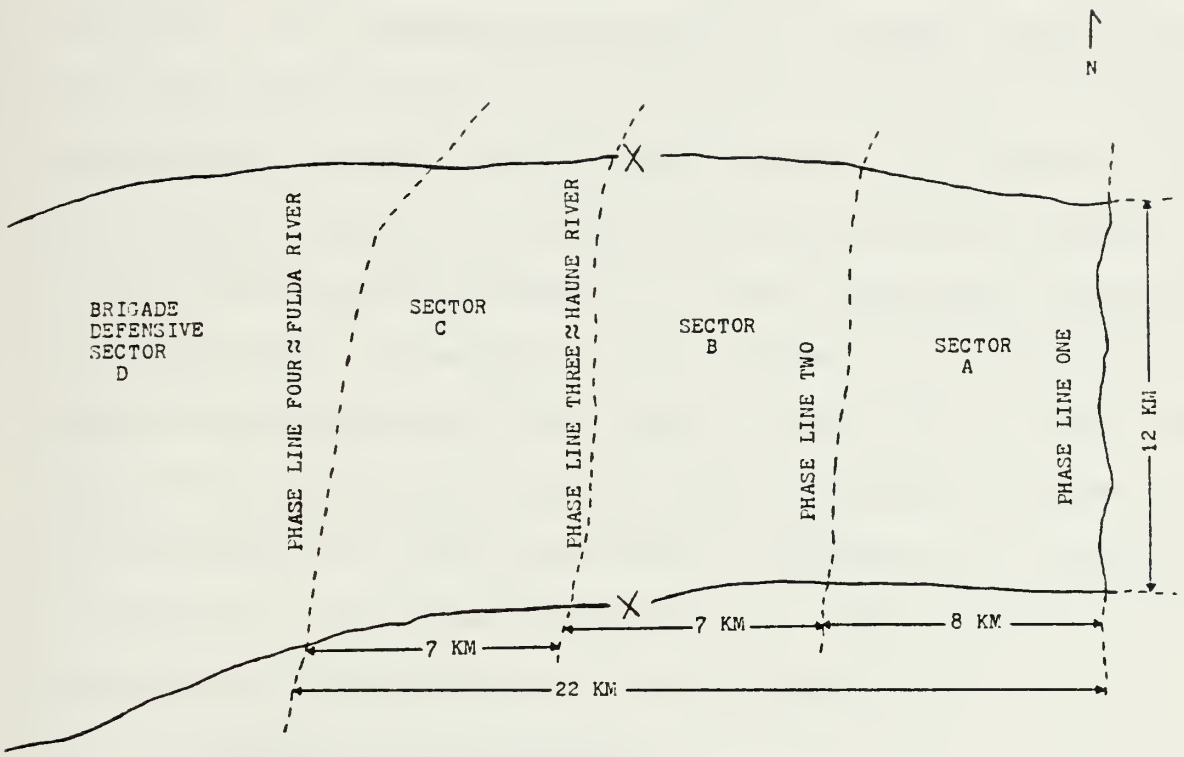

Figure 8. Brigade Delay Sector Dimensional Analysis

reduction of forces allocated to reserves and rear area protection. For each course of action, a phased maneuver concept, task organization and timeline are specified. This technique was employed for the simulated delay. Each course of action generated was based on terrain as well as forces available. If a subsequent mission is stated, the desired starting condition for the subsequent mission establishes the end condition for the initial mission. All courses of action should result in a reasonable transition of forces to the specified starting condition of the subsequent mission. This technique is based on the concept of exploratory scenarios proposed by Thomas Saaty. [Ref. 25: p. 125] The commander and operations officer might develop schedules for each alternative on the map board to generate the timeline and sequence of combat activities. This technique is constrained by the planning time available.

7. Analysis of Alternatives

Up to this point in the process, the principal participants in planning and analysis of the new mission have been the brigade commander, operations officer and intelligence officer. The other members of the brigade staff provided input to the commander's information update which highlighted subsystem limitations. Based on this input, the commander executed the planning sequence which resulted in a finite set of maneuver alternatives. These alternatives are now examined by each technical subsystem

commander and staff for supportability. While the supporting subsystems staff officers perform their analyses, the brigade operations and intelligence officers perform a detailed analysis of alternatives with respect to maneuver outcomes.

The basis for the maneuver analysis is the projection of baseline or normative outcomes in terms of surviving fully manned weapon systems over time. The input data for this analysis is the starting strength of each maneuver battalion, the level of combat over time for each battalion and the type terrain over time for each battalion. The projection employed for the delay simulation was an exponential type decay function but might also have been approximated with a linear decay model. Data from the delay simulation was analyzed to obtain representative normative decay rates. Figure 9 provides an example of the results of this type of predictive model for a specific course of action. The course of action analyzed was Course of Action I which committed TF1-12 (ARMOR) in Sector A and TF1-10 (Balanced) and TF1-92 (Balanced) in Sectors B and C. All units were committed in the subsequent sector defense. The brigade result is an aggregation of the results of each of the battalion parametric analyses. Figures 10 and 11 provide a detailed description of M1 and IFV strengths over time for the same scenario. As a further example of this technique, Figure 12 shows the case of a prediction which

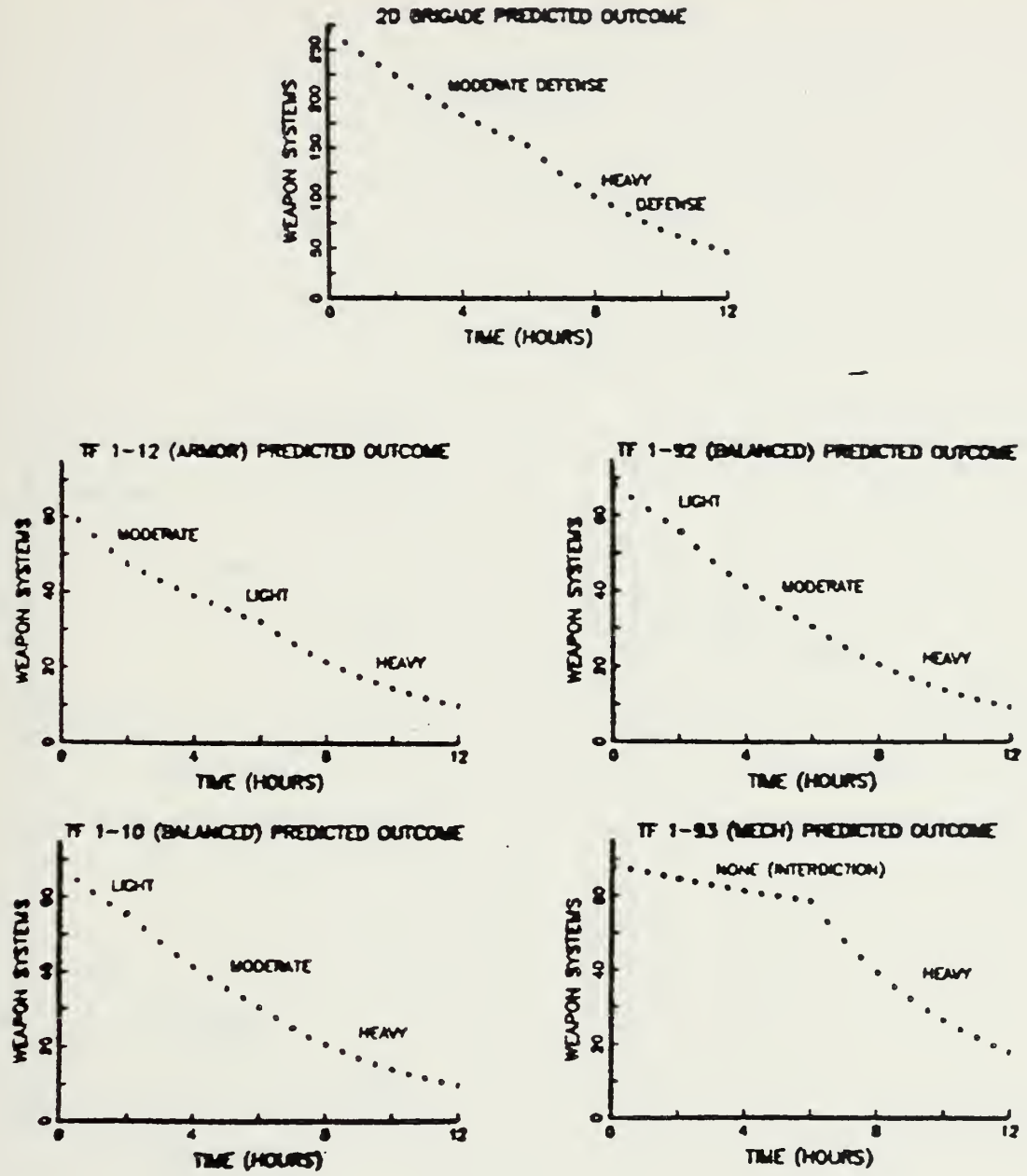

Figure 9. Maneuver Force Outcome Projection.

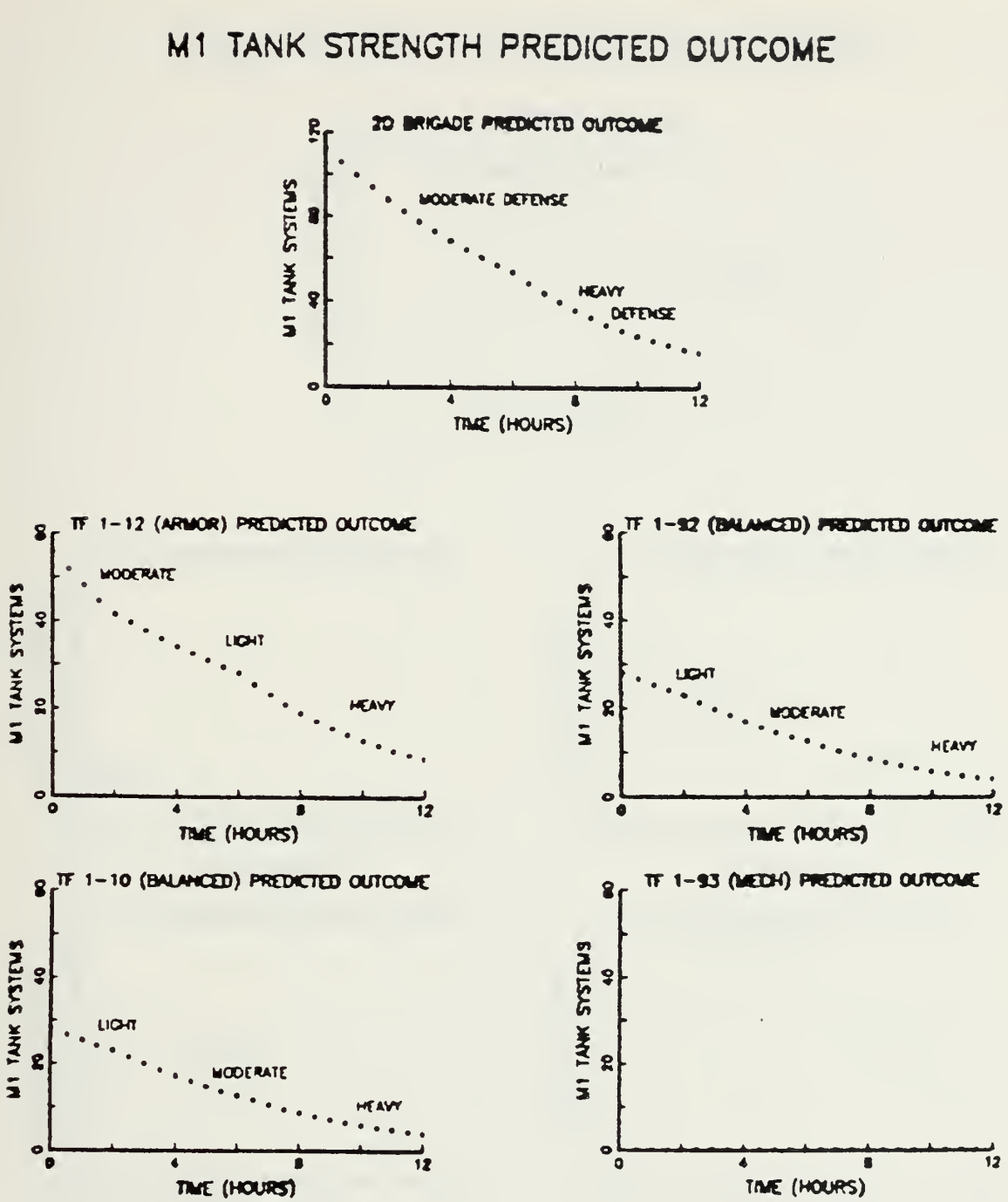

Figure 10. M1 Tank Outcome Projection.

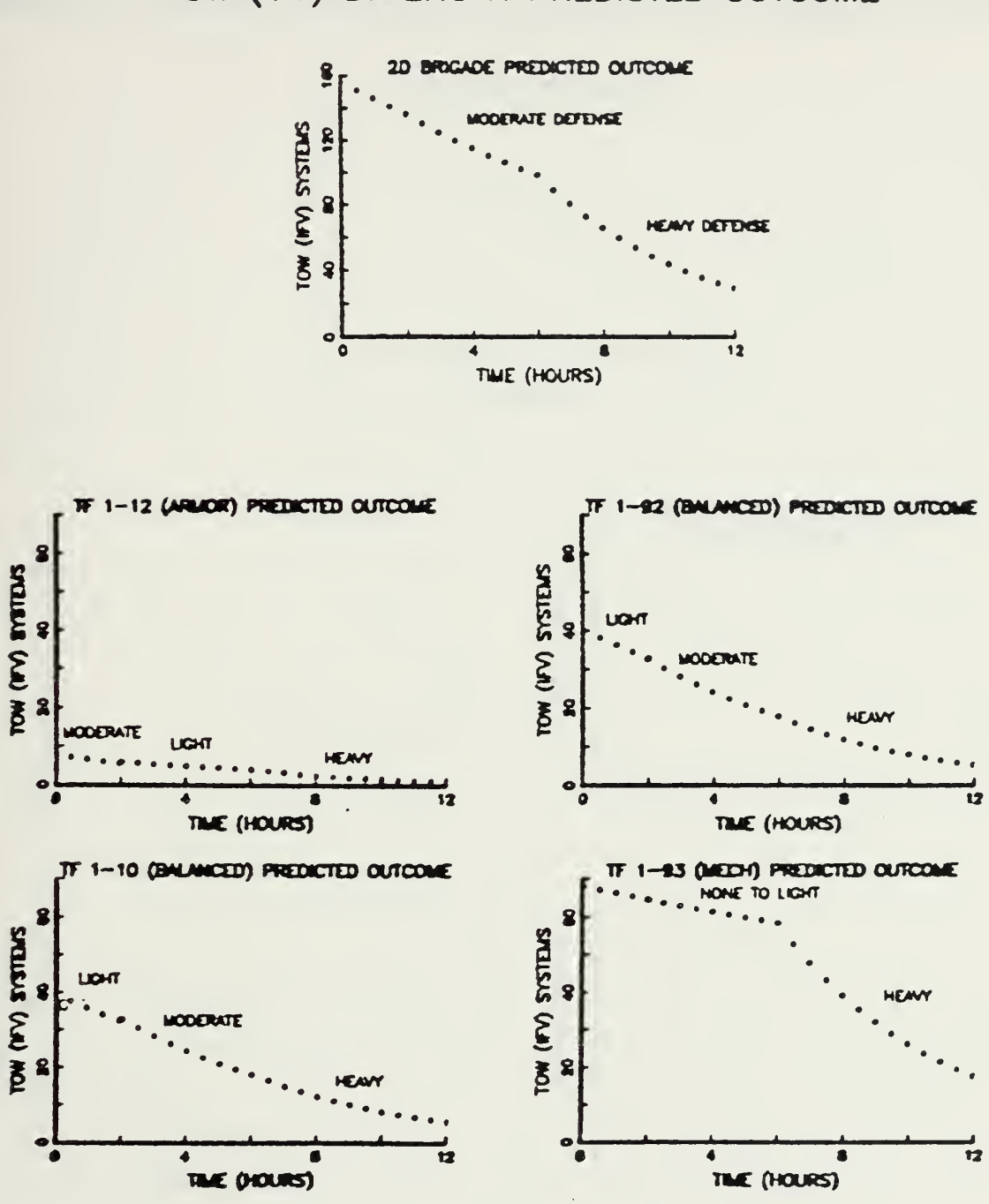

Figure 11. TOW (IFV) Outcome Projection.

WEAPON SYSTEMS PREDICTED OUTCOME (WITH REINFORCEMENTS)

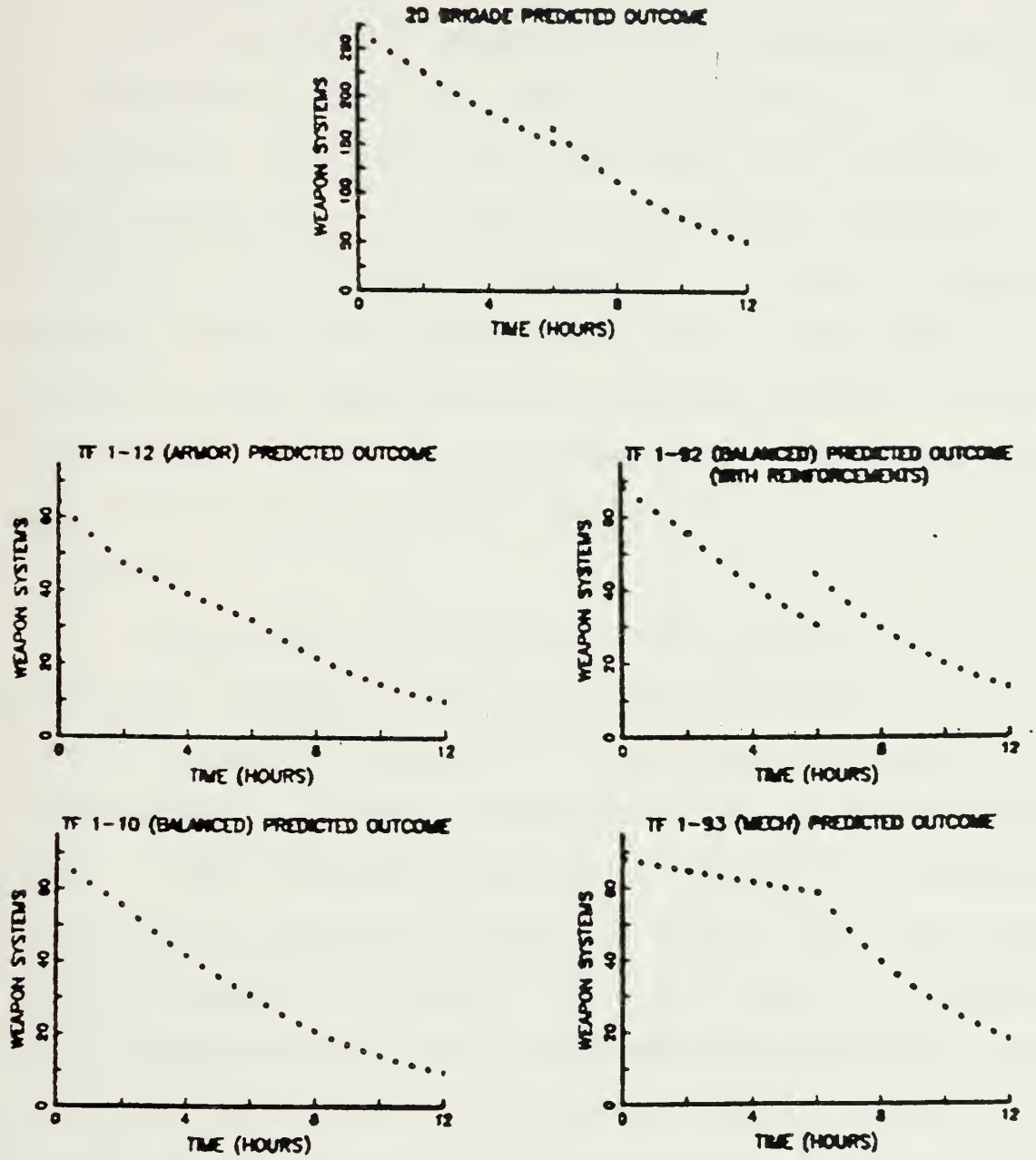
2D BRIGADE PREDICTED OUTCOME
WEAPON SYSTEMS
TIME (HOURS)
TF 1-12 (ARMOR) PREDICTED OUTCOME
TF 1-82 (BALANCED) PREDICTED OUTCOME
TF 1-10 (BALANCED) PREDICTED OUTCOME
TF 1-93 (MECH) PREDICTED OUTCOME

Figure 12. Maneuver Force Outcome Projection With Reserve Committed at H+6 Hours.

involves a commitment of a reserve tank company to the brigade at H+6 hours. The method proposed is flexible and may be adjusted for lateral repositioning of forces.

An alternative approach to the parametric analysis of alternatives described above is a subjective prediction of battalion loss rates for each phase of the operation. These projections are made by the brigade commander or operations officer and are aggregated to create an expected brigade outcome for each alternative. The result is a piecewise linear approximation which may be used to compare alternatives. Figure 13 is an example of a piecewise linear approximation for Course of Action I for the delay simulation.

Regardless of technique, the consolidated result would be a graph of the form shown in Figure 14. This specific figure was generated by parametric analysis of the three courses of action developed for the simulated brigade delay. This forecast provides a method for comparing alternative maneuver courses of action and may expose clearly unacceptable alternatives. In Figure 14, it appears that Course of Action III is dominated by the other courses of action in terms of surviving weapon systems. The magnitude of dominance, in this particular case, is not large but might be cause for elimination of the dominated course of action.

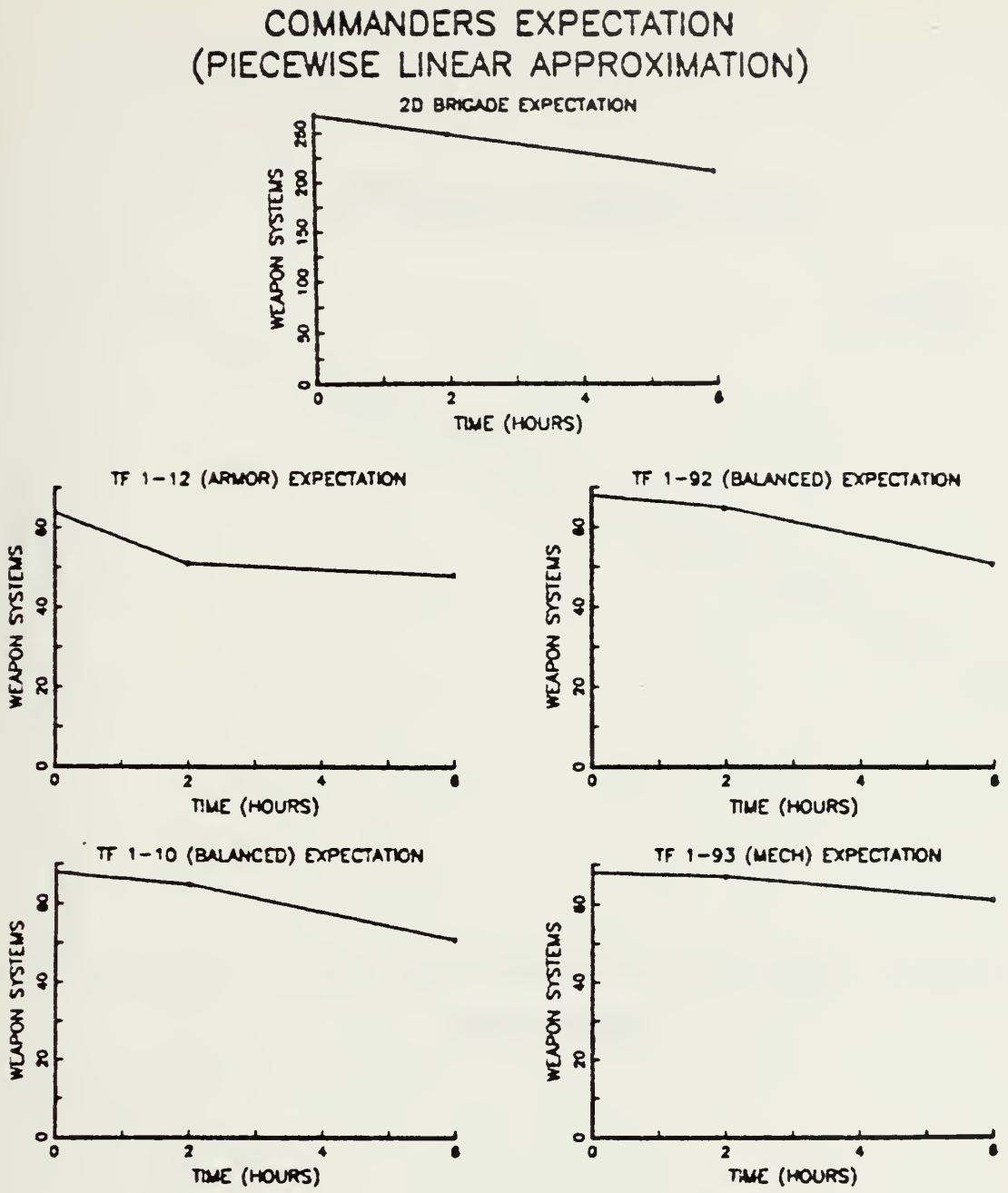

Figure 13. Subjective Projection of Outcome.

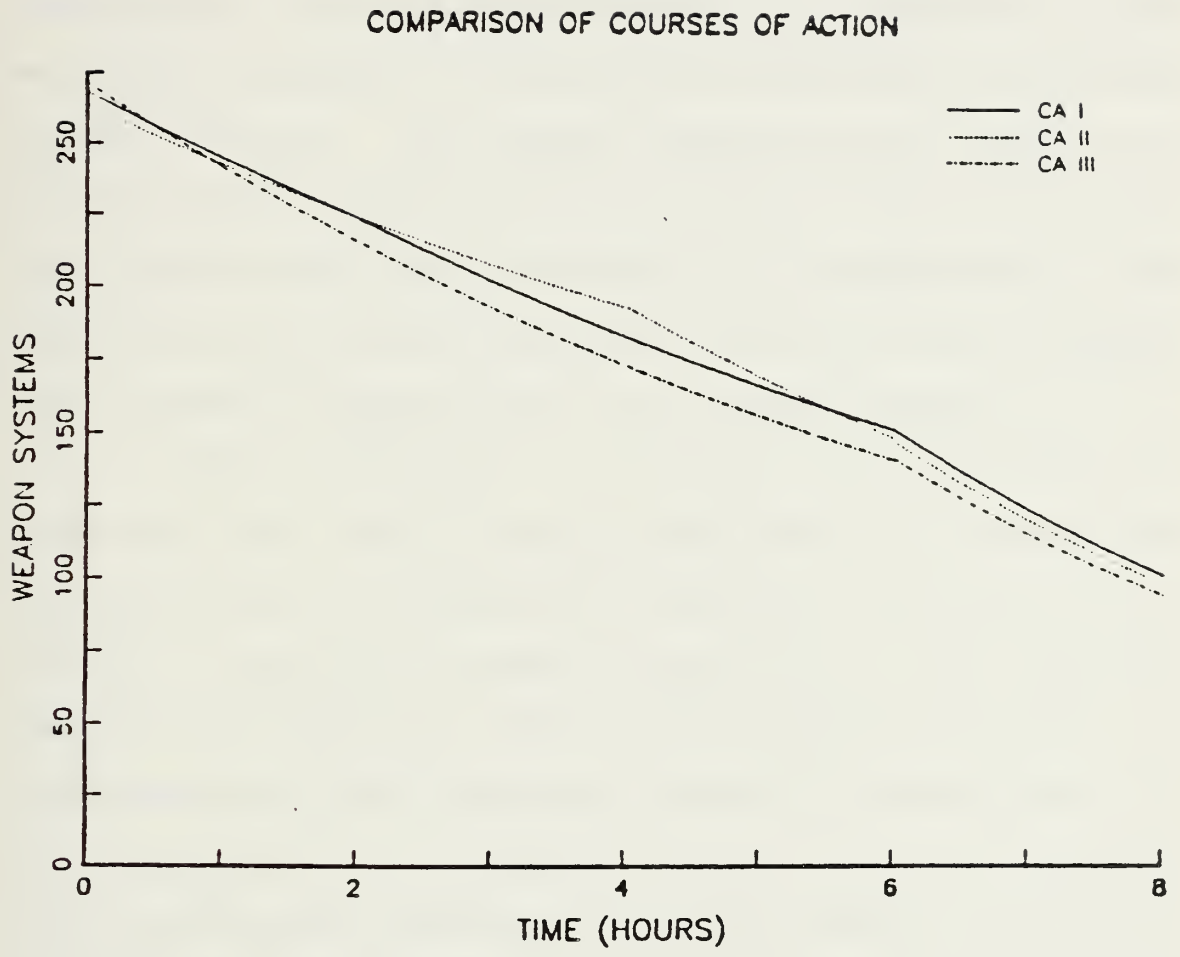

Figure 14. Parametric Comparison of Alternative Courses of Action.

The exponential or linear loss rate approximating techniques suggested above are employed to execute comparative analysis of maneuver alternatives. They provide a technique which quantifies the maneuver battle for each alternative. The parameters used for the example were based on a single iteration of First Battle and should be examined in that context. The simple deterministic approach is proposed as an alternative to a detailed high resolution simulation which would probably be unresponsive to the immediate needs of the commander and which would probably also exceed the capacity of the automated systems.

Similar analyses of maneuver alternatives are performed by each supporting technical subsystem representative. The specific techniques employed would require a technical support analysis of each maneuver alternative to identify resource constraints which place the alternative at risk. An example might be a determination by the engineers that a maneuver course of action exceeded available bridging capabilities. These resource limitations are the basis for support subsystem inputs to the decision process. The proposed input mechanism for these support subsystem analyses is an ordinal ranking system which at least identifies maneuver courses of action which are at risk due to supporting resource constraints.

A feasibility evaluation of each maneuver alternative by each support subsystem might be a binary

indicator variable (zero or one) which indicates that the alternative is supportable (one) or exceeds support resources (zero). Coordinating staff officers might act to reduce "zero" situations by resource tradeoffs across subsystems or by force augmentation from external (division) resources. Explanation of all unresolved "zero" conditions would be provided to the force commander for consideration prior to his decision.

A preference evaluation of each maneuver alternative by each support subsystem might involve pairwise comparison of each maneuver alternative with the other maneuver alternatives. In The Analytic Hierarchy Process, Thomas L. Saaty describes a method for employing this technique. [Ref. 26] Saaty proposes an ordinal ranking scale which ranges from 1 to 9. Pairwise comparisons result in reciprocal rankings of alternatives. Numerical techniques are employed to determine relative preference of alternatives. These rankings might be aggregated for all force subsystems to obtain a force preference evaluation of alternatives. This preference evaluation approach may exceed the force commander's requirements. The feasibility evaluation of maneuver alternatives by the support subsystems may be adequate and responsive to the force commander's needs.

8. Commander's Decision and Detailed Guidance

The quantitative analysis of maneuver alternatives is combined with the force commander's qualitative evaluation to achieve a decision concerning the specific maneuver course of action to be executed. The commander clarifies his concept of the maneuver battle to the brigade operations officer and subordinate maneuver commanders. This clarification might include specification of quantitative goals for maneuver units in the dimensions of time, location and weapon system.

The brigade operations officer employs this guidance to establish normative performance envelopes for each battalion or task force and an aggregated envelope for the brigade. Figure 15 is an example of weapon system performance envelopes. These envelopes were based on the scheme of maneuver for the simulated brigade delay. They were derived from the piecewise linear approximation shown at Figure 13. The lower bound of the weapon system performance envelopes represents a ten percent negative deviation from the commander's goal. If the brigade or subordinate task force strengths approach this bound, an unsatisfactory condition exists which may require a change or adjustment to the maneuver plan or allocation of support resources. This graphical technique is a primary tool which may be used by the operations officer during the control cycle to monitor execution of the delay. Figure 16 is an

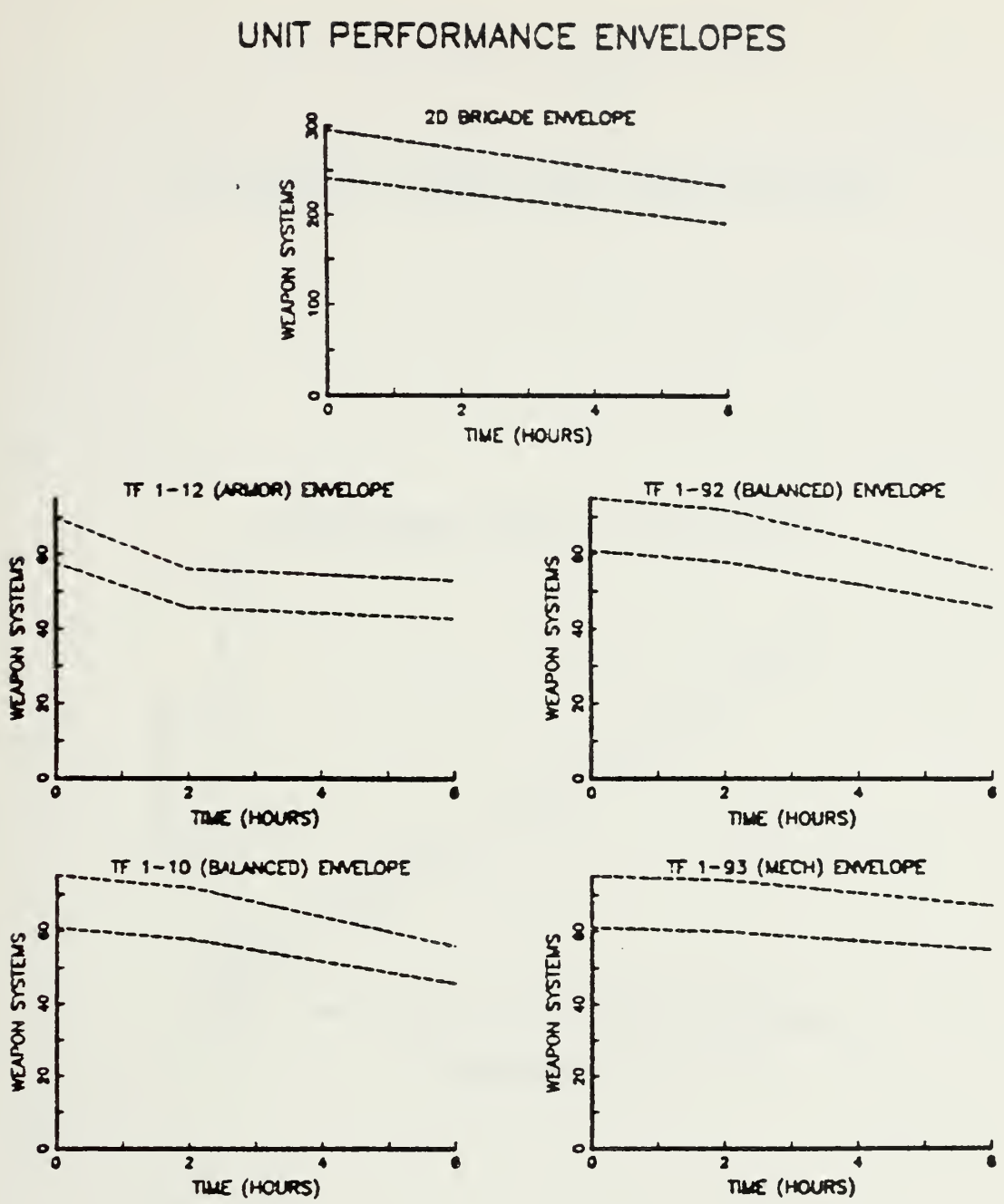

Figure 15. Brigade Weapon System Performance Envelopes

2D BRIGADE FRONT LINE TRACE ENVELOPE

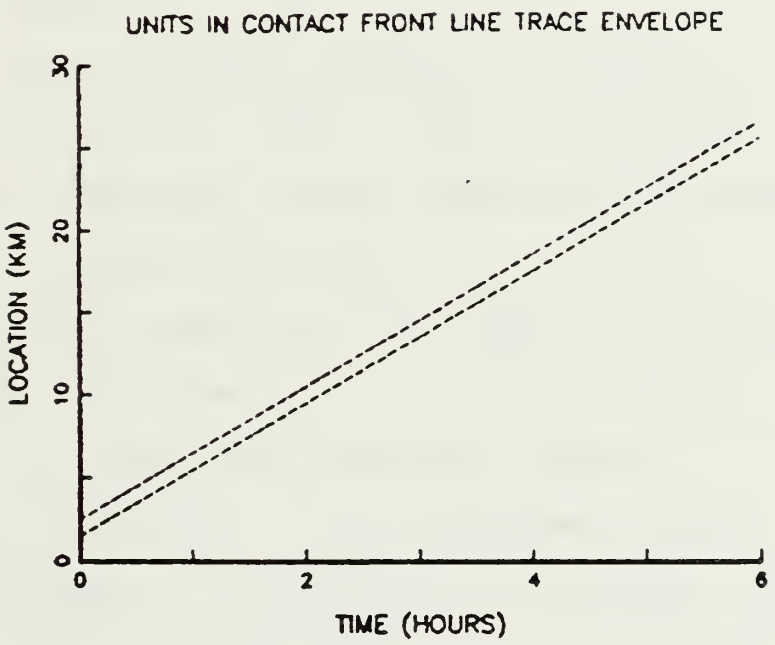

Figure 16. Brigade Front Line Trace Performance Envelope.

example of a brigade front line trace performance envelope. This specific envelope was also based on the scheme of maneuver for the simulated brigade delay. The upper bound of the front line trace envelope represents a twelve percent deviation from the commander's goal. This envelope assists the brigade operations officer to track unit performance with respect to delay rate over time to identify marginal or unacceptable conditions. Use of these tools will be demonstrated in the following sections which examine the control cycle.

The envelopes presented in Figures 15 and 16 are generated based on the brigade commander's clarifying guidance. The weapon system performance envelope in Figure 15 was developed by generation of a plus or minus ten percent region about the commander's expectation shown in Figure 13. The size of the region indicates the degree of sensitivity which the commander desires. The boundary of the specified region is the commander's explicit threshold. If the boundary is approached or exceeded, the commander expects to be notified and involved in formulation of remedial action.

The techniques presented above are designed to assist the brigade commander and his staff in the development and relative comparison of force alternatives to accomplish a newly assigned mission. A sequence of standard procedures is executed which assists the commander in his

analysis of the current situation and the projection of alternative outcomes. Supporting subsystems provide input to the brigade commander's decision process. The coordinating staff provides a filtering mechanism for this input as it seeks to resolve conflicts or resource constraints which may limit the brigade alternatives.

These proposals are not all inclusive but suggest a starting point for analytic techniques which have potential for application with the advent of automated components in the force command control system.

E. ANALYTICS IN THE CONTROL CYCLE

The brigade operations plan has been disseminated to subordinate units for execution. The brigade commander leads the maneuver force in the aggressive execution of the plan. The brigade staff coordinates execution by monitoring the situation, by comparison of actual battle conditions with explicit expectations and by subsequent identification of opportunities or discrepancies. The brigade staff may employ analytic techniques within the control cycle to identify trends and discrepancies. Steps of the control cycle which suggest such applications are numbered in Figure 17. The following subsections correspond numerically to these steps and describe the techniques which might be employed.

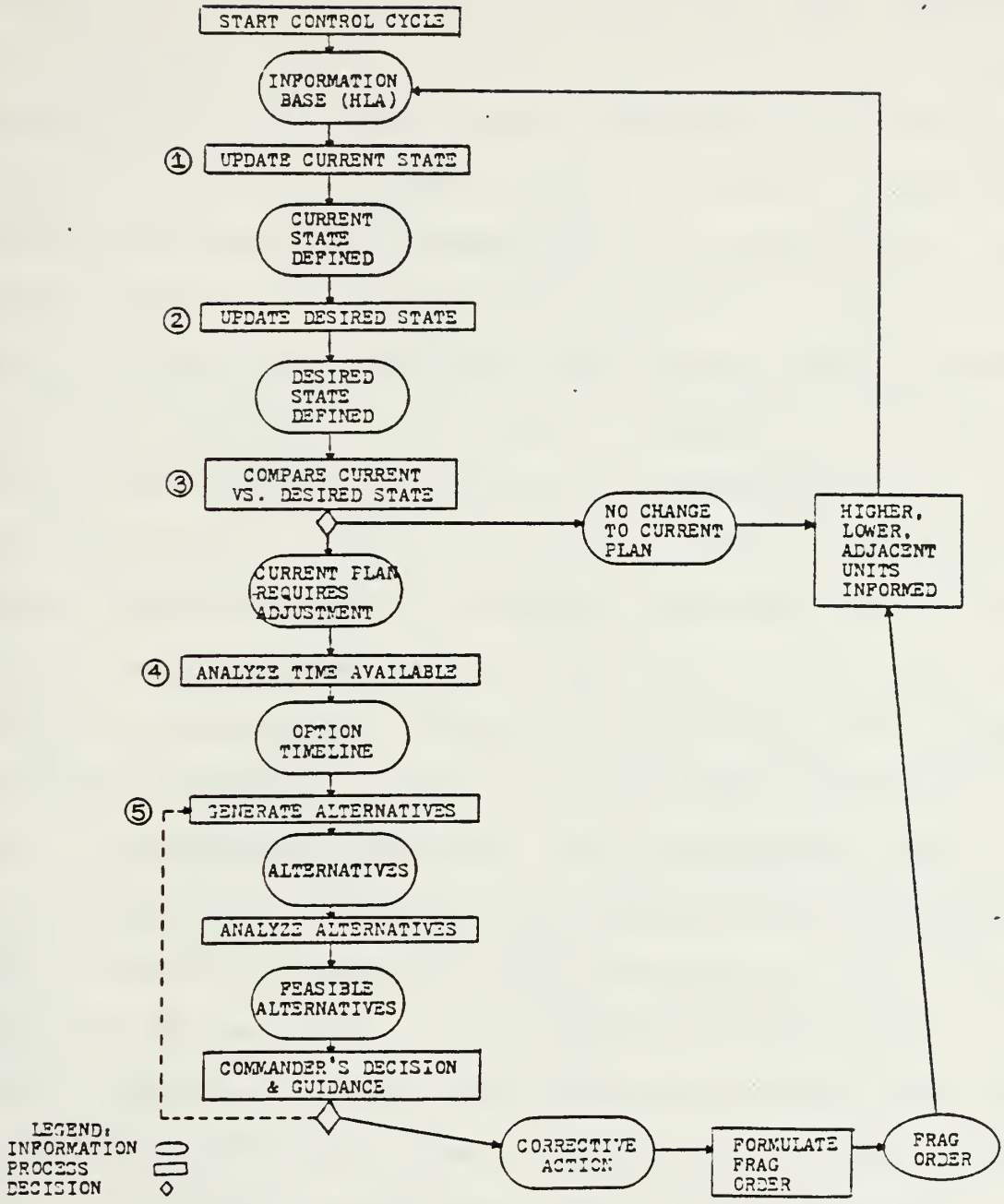

Figure 17. Control Cycle Process Model (Numbered).

Several figures are presented in this section to provide examples of the force condition over time. These examples are based on the actual data obtained from the delay simulation and the performance envelopes presented in Figures 15 and 16. Figure 18 is an example of the unit performance envelopes developed for the brigade delay. The reader should note that the two graphs at the top of the figure reflect the brigade goal for weapon system strength and front line trace over time. Figures 19 through 21 present the actual sample data points obtained from the delay simulation at H+2, H+4, and H+6 hours respectively. These figures graphically display the comparisen of the current and desired state. They assist the staff to identify discrepancies. Figure 22 is an example of a linear regression analysis of data obtained from the first two hours of the simulated delay. This regression technique might be applied to quantify the trends of current tactical operations and to make limited predictions of the future condition of the force. It is extremely important that the reader understand that these predictive techniques rely heavily on stable conditions of combat for short periods of time. If a sound operational plan is being executed, the necessary stability to make predictions about the future may be induced. The regression model of recent combat may assist the commander in his analysis of alternatives.

UNIT PERFORMANCE ENVELOPES

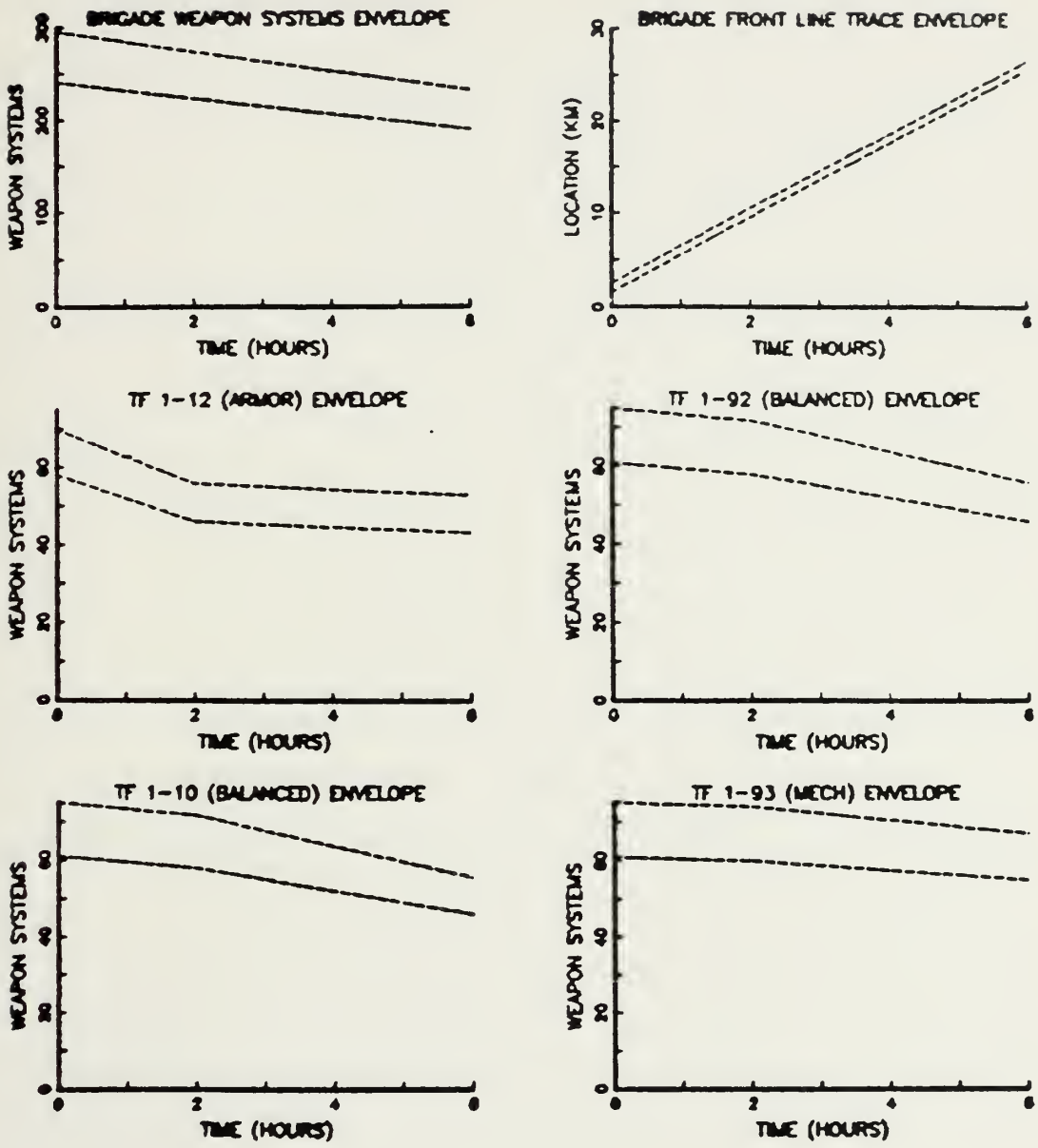

Figure 18. Unit Performance Envelopes.

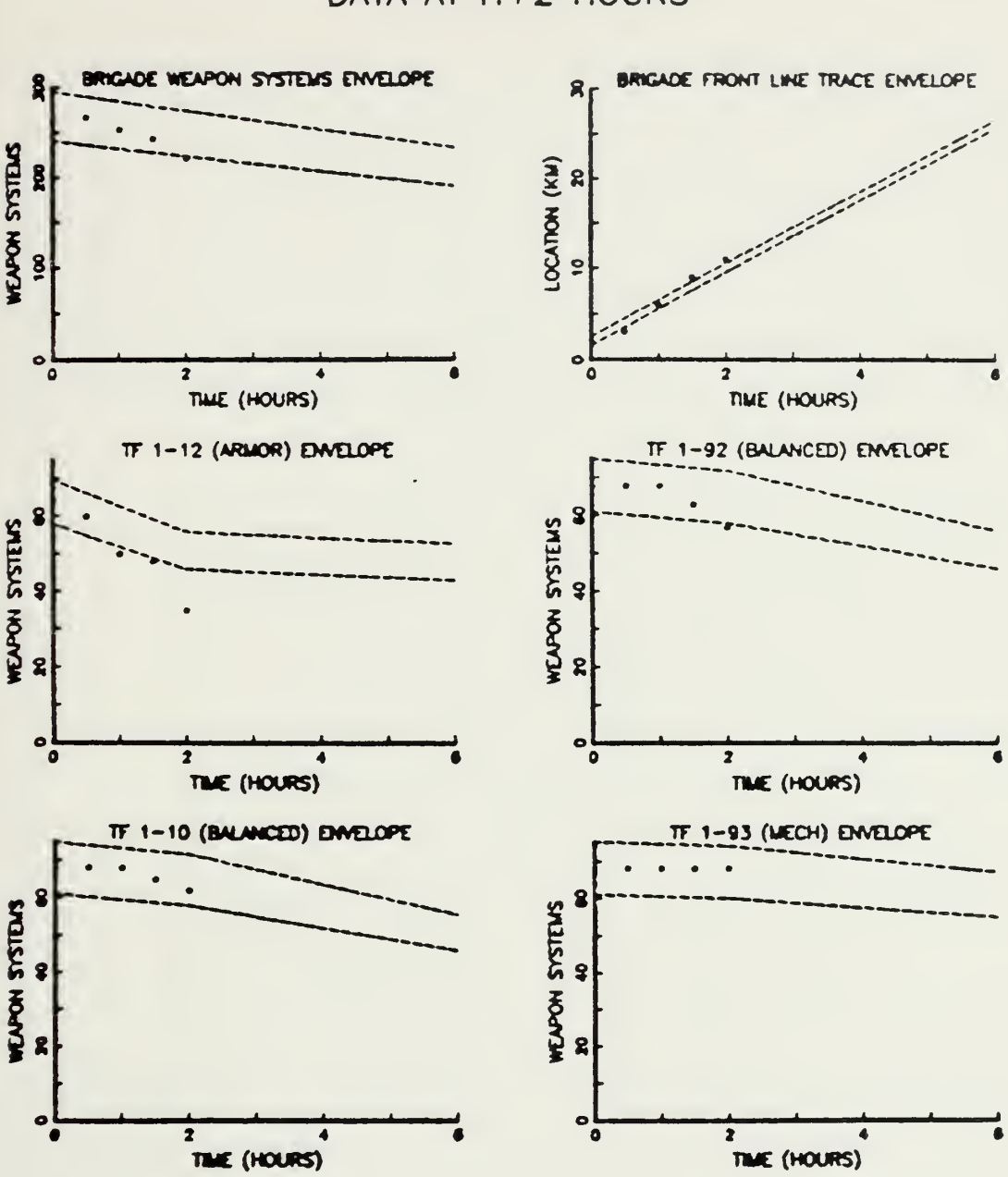

Figure 19. Brigade Performance at H+2 Hours.

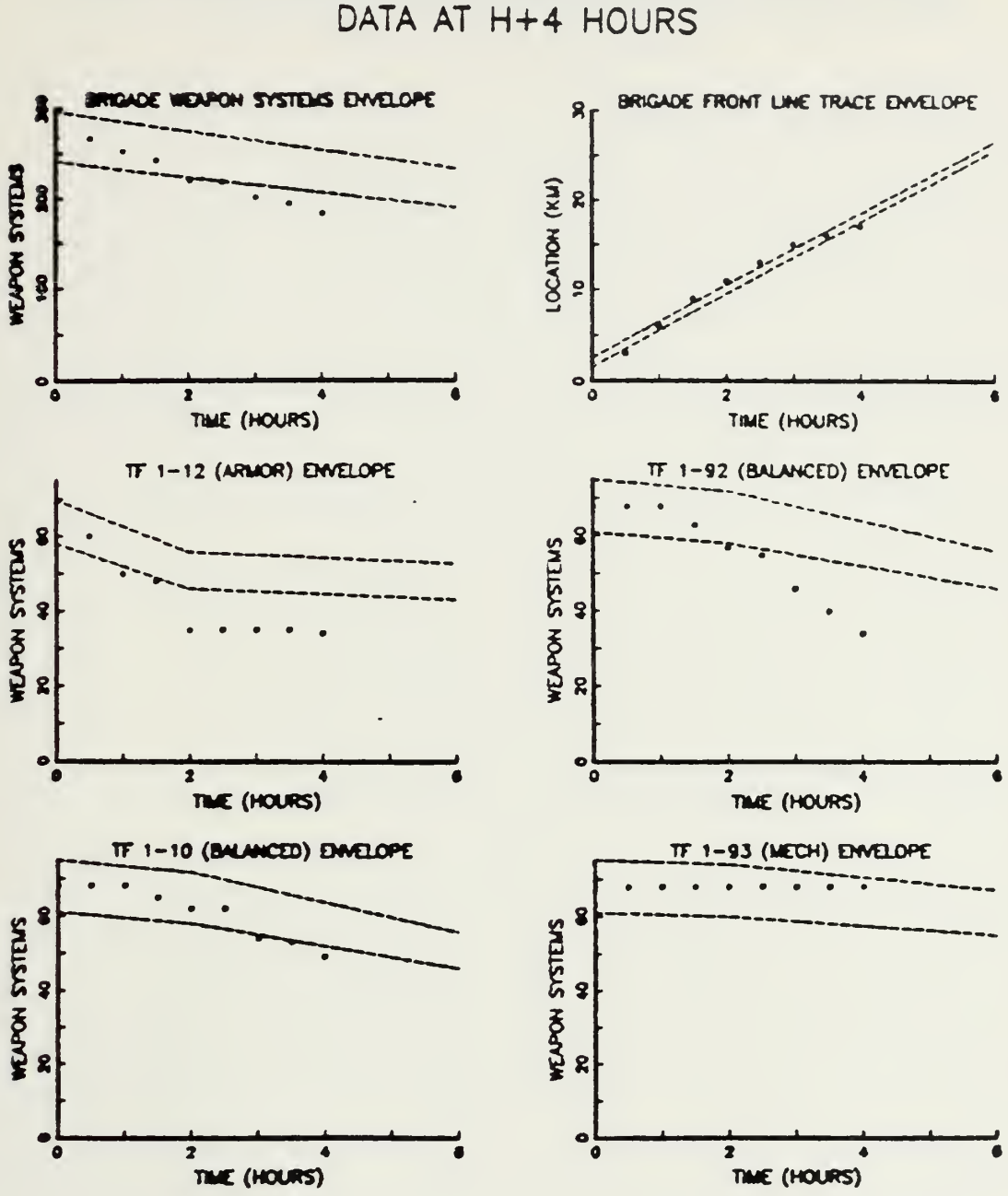

Figure 20. Brigade Performance at H+4 Hours.

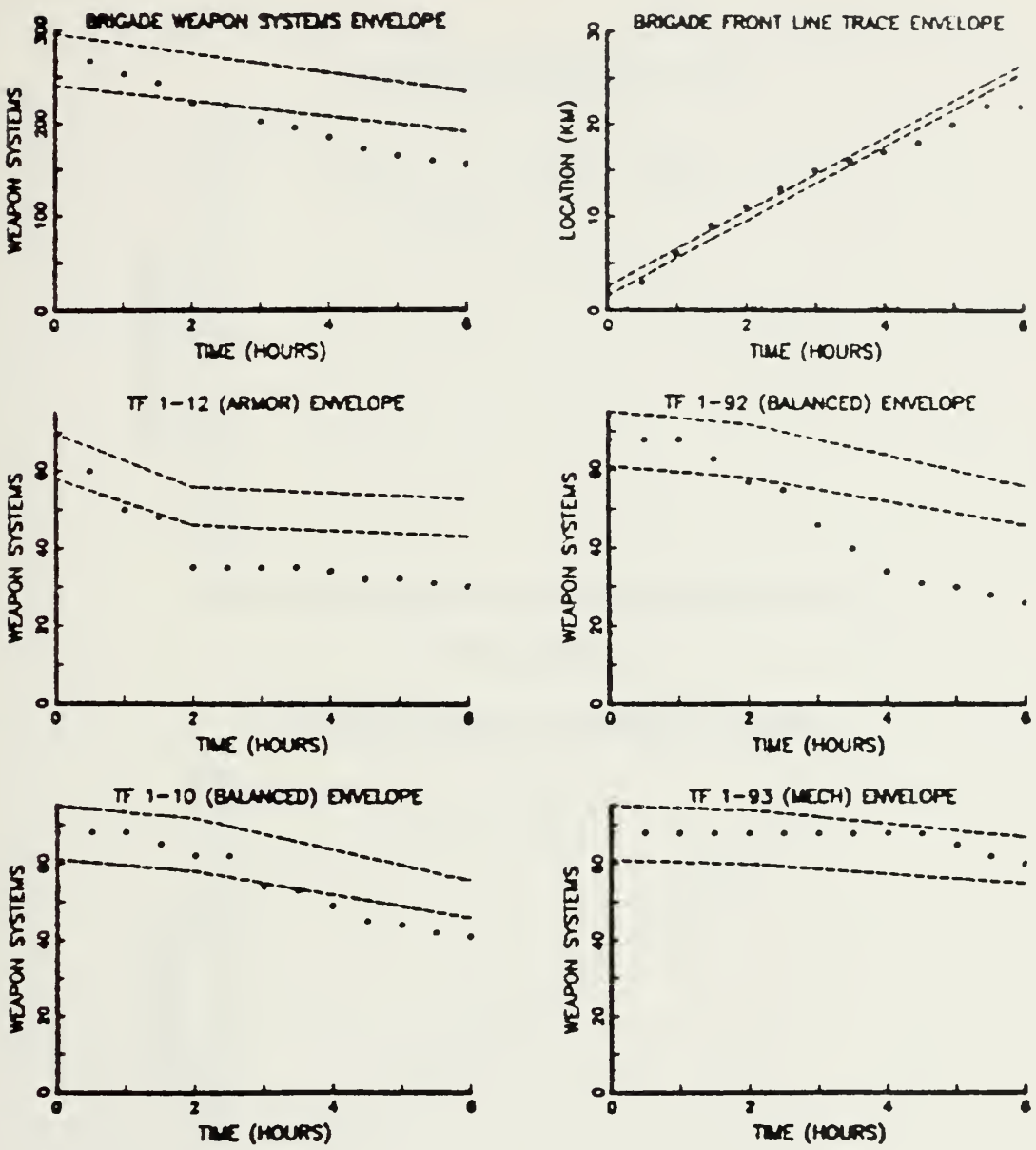

Figure 21. Brigade Performance at H+6 Hours.

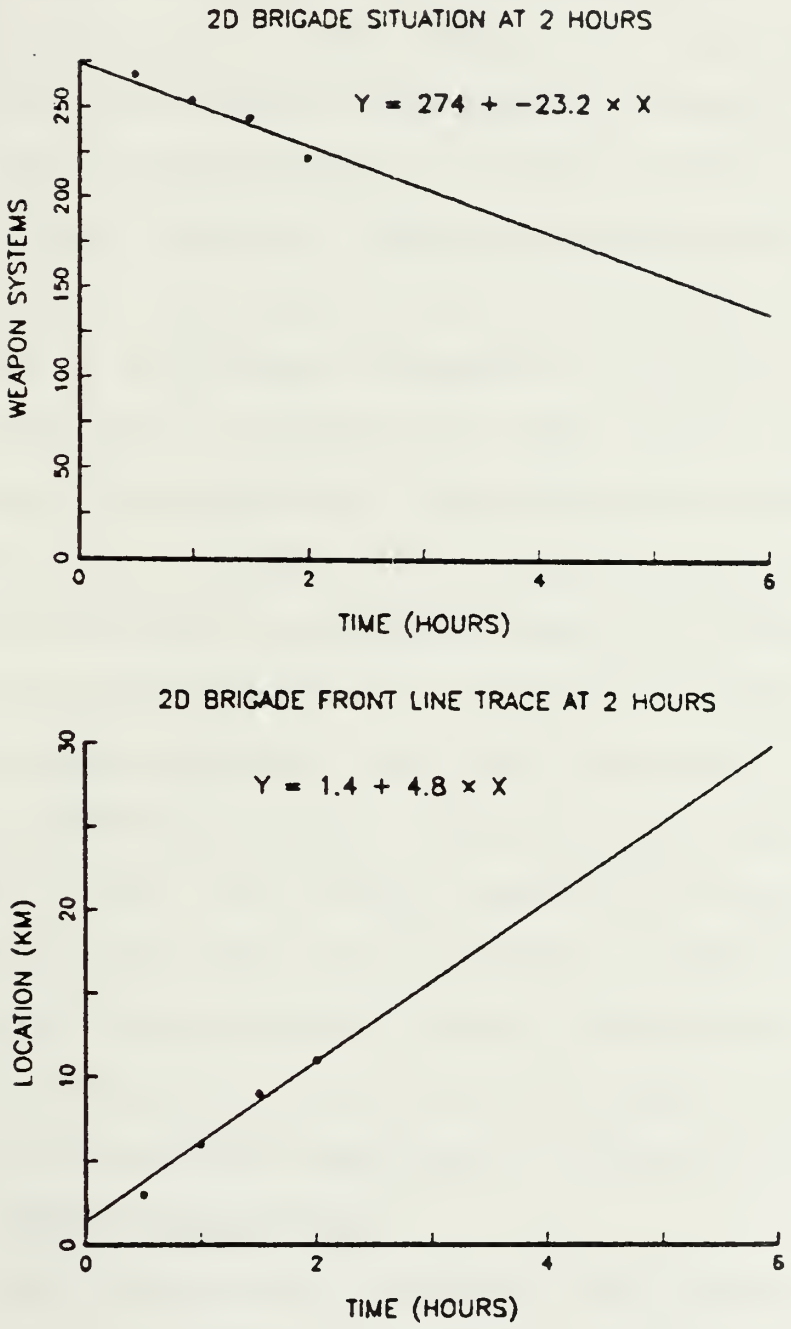

Figure 22. Regression Application to Brigade Delay.

1. Update Current State

Subordinate unit situation reports are processed to update the force situation and front line trace. Weapon system strengths and front line trace are plotted on graphs similar to Figure 15 and Figure 16. The intelligence section may use similar techniques to identify trends in enemy force concentrations to compare with the expected enemy course of action. These representations provide a quantitative description of the brigade which is a supplement to the brigade commander's qualitative analysis. Similar tracking is executed for each support subsystem of the force. The graphical representations enable visual interpretation of trends. Future force conditions might be predicted with some confidence based on continuation of current tactical operations. Figure 22 shows a linear regression application to the first two hours of data from the simulated brigade delay. This predicted result compares favorably with the actual outcome achieved for the subsequent four hours of the delay. These trends may provide the brigade staff with a technique to perform tradeoff analysis; to tune priorities of support or allocation of subsystem resources to competing alternatives.

2. Update Desired State

The brigade staff reviews the currently defined desired state to determine if it is still valid. The desired state may have changed due to a change in force

organization or as a result of a change in command guidance. Initially, the commander and staff might seek to achieve stability by executing the plan and holding the desired state constant until trends are identified. This is in contrast to "rapid cycle decisioning" which has been suggested in some publications. [Ref. 24] The desired state is graphically portrayed as a performance expectation envelope. The width of the envelope creates thresholds of sensitivity for identification of discrepancies.

3. Compare Current Versus Desired State

The actual conditions are plotted and compared with the defined desired state to identify discrepancies. Subordinate unit conditions are aggregated to yield a brigade description. The comparison might be performed by visual inspection but could also be examined automatically against preset thresholds. Exceptional conditions might be reported to the operations officer as they are identified. In Figure 19 such a discrepancy occurred for Task Force 1-12 at H+2 hours. This discrepancy was identified in the actual execution of the delay. The succeeding tactics employed sought to move the task force into the range of expectations while maintaining the desired delay rate.

The comparison step may indicate that the current plan is being executed effectively and no adjustments are required. Unit performance levels which exceed the commander's expectations may indicate an opportunity to

seize the initiative. Unacceptable discrepancies may suggest that immediate changes must be invoked to avert disaster.

Changes are planned and executed in an abbreviated decision cycle which may employ selected tools previously presented in the initial planning sequence.

4. Analyze Time Available

A regression approach or a visual extrapolation of trends using recent combat data will aid in the definition of the time available to correct a discrepancy with resources organic to the brigade. This analysis may result in the determination that the only means to resolve the discrepancy lie outside the brigade's resources. Initially, the brigade staff seeks to generate alternatives within the time constraint and available internal resources.

5. Generate Alternatives

In contrast to the initial planning sequence, alternative generation in the control cycle involves adjustment of current operating policies of support and maneuver based on recent combat operations. The brigade commander and operations officer seek to identify cause and effect relationships. Each supporting subsystem may be investigated to analyze its potential contribution to correction of the discrepancy. Time is the critical constraint on alternative generation and analysis in the

control cycle. Delayed or inadequate responses may accelerate the need for major changes to the current plan.

The delay simulation executed by the authors using First Battle did not facilitate effects analysis for specific corrective actions. Some corrective actions which might be applied to reduce losses while achieving the desired delay rate are a change in tactics of maneuver forces, a change in allocation of engineer resources to countermobility operations, or a change in allocation of fire support resources. Perhaps the key concept suggested here is to examine adjustment possibilities within the support subsystems before invoking a change in the scheme of maneuver. This approach results in a sequence of corrective action execution, evaluation of results and subsequent adjustment within the control cycle.

The analytic tools described in this section may provide an improved measure of force performance during mission execution. They facilitate identification of unacceptable discrepancies and assist the staff to identify trends in a combat environment. They are recommended as a quantitative supplement to the qualitative evaluation performed by the force commander during combat operations.

VII. CONCLUSION

This thesis has developed and examined a model of the force command control process for a U.S. Army Maneuver Brigade executing a delay mission. The model was exercised and revised by execution of a simulated delay using the First Battle Combat Simulation. The theory employed to develop the model emphasized the necessity of a systems approach to the problem of force synchronization.

Potentially useful analytic tools were developed for application during specific steps of the command control process. These tools are designed to assist the force commander and his staff as they execute planning and control tasks during combat operations. The key concept which these tools focus on is the projection, measurements and comparison of force levels over time. This thesis has been necessarily restricted to trend analysis within the maneuver force for a specific tactical mission. An area of potential examination is the description and prediction of other technical subsystems' capability and actual performance in support of the maneuver force.

These tools have limited feasibility in a manual command control system but may have a higher likelihood of widespread use with the advent of automated components in the force command control system. While this study has

focused on the maneuver brigade level of the force, the tools may have greater potential for application at higher levels of the force.

This thesis suggests that a component of the automated command control systems might include parametric models to enable relative comparison of alternative courses of action over time, terrain and levels of combat. These parametric predictions may enhance the commander's subjective analysis of alternatives.

This study has provided an approach to the development of specific analytic tools in the tactical command control process. Subsequent studies might address applications for other echelons of the force, applications for other tactical missions and applications for other key scenarios.

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